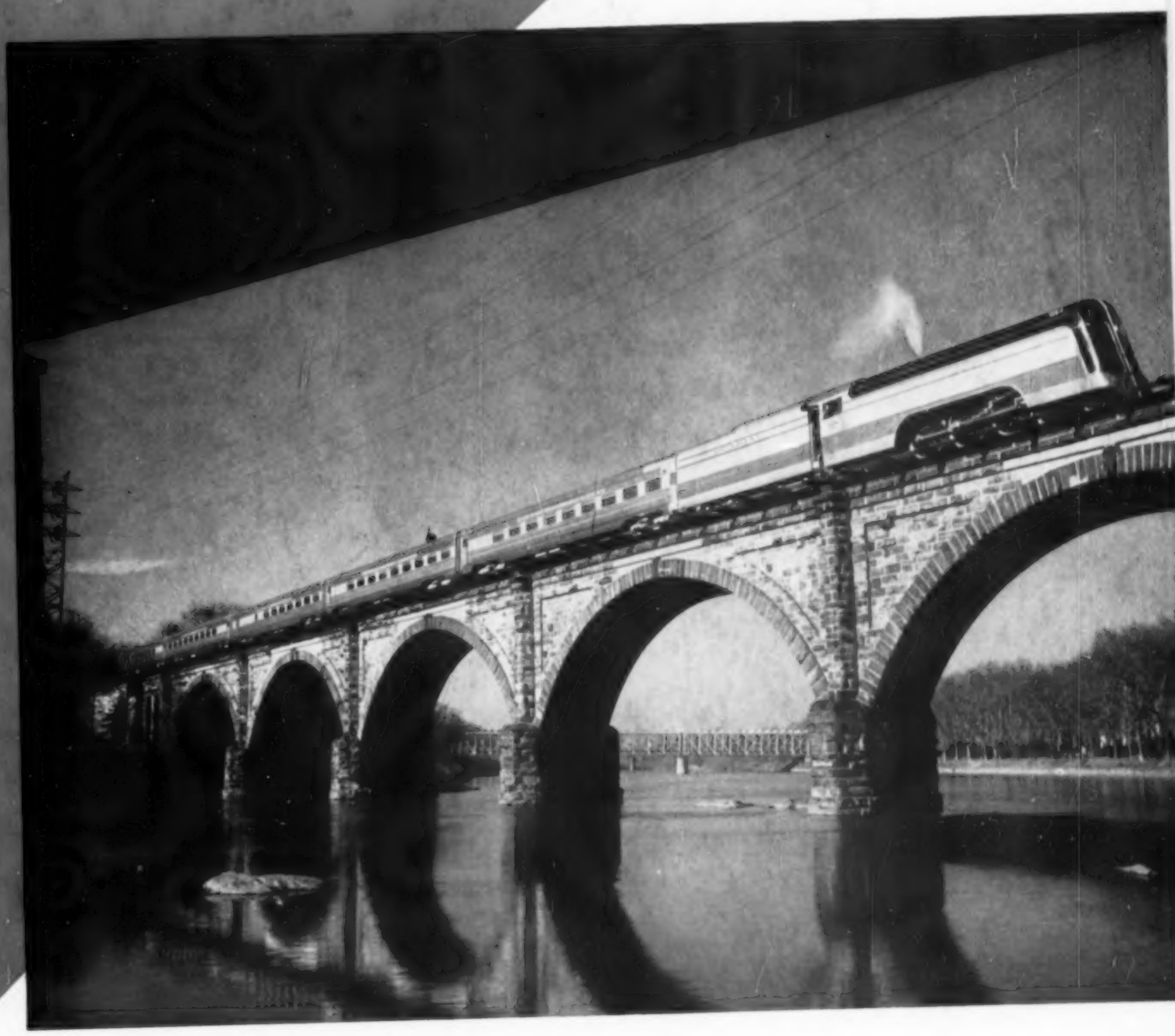
METAL PROGRESS



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MAGNESIUM ALLOYS AND THEIR USE IN AIRCRAFT

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THE SAFETY, comfort, and performance of the modern airplane are made possible largely through the availability of new light weight, high strength materials, among which magnesium alloys are occupying an increasingly prominent place. Their outstanding characteristic is their lightness, all of them having a specific gravity of less than 1.85; this is but two-thirds the weight of aluminum and less than one-quarter the weight of steel. Light weight is combined with good mechanical properties on a volume basis, resulting in the highest obtainable strength-weight ratios among comparable materials. Fabricated forms include sand castings, die castings, forgings, extruded shapes, sheet, all of which are used in the construction of aircraft. As production costs have lowered, consumption of the various forms has increased, not only in aircraft applications but in many other industrial uses.

While magnesium was first discovered in 1808, little structural use was made of the metal until 1909 when commercial exploitation of the alloys began in Germany. The American magnesium industry had its start in 1915, in answer to a demand for the metal for military purposes. While there were five producers in 1917, there is but one in operation at this time, The Dow Chemical Co. at Midland, Mich. The metal is obtained with a purity of 99.9% by the electrolytic reduction of magnesium chloride, which is recovered from the salt brines underlying central Michigan at a depth of 1200 to 1400 ft. The process was outlined by John A. Gann in METAL PROGRESS for April 1932.

Magnesium, as is the case with most pure metals, is soft and requires alloying to fit it for structural applications. Commercially pure metal is used, however, for a number of non-structural applications, including:

1. Low percentage constituents of other alloys, notably those of aluminum.
2. Deoxidizing agent, for nickel and other alloys.
3. Powder for flares and other pyrotechnics.
4. Chemical reagent, principally for the Grignard reaction in organic synthesis.

At the present time the consumption of magnesium for these uses is approximately half the total in this country. This ratio is becoming smaller, as uses in the alloyed form for structural purposes is increasing much more rapidly. The latest official figures from U. S. Bureau of Mines "Minerals Yearbook", and shown on the bottom of page 238, give the distribution of American production in 1938 in the various forms in which magnesium and its alloys are used.

A question occasionally is raised concerning the adequacy of the raw materials for the production of magnesium. Magnesium is the third most abundant structural element in the earth's crust, being surpassed only by iron and aluminum. The United States possesses practically inexhaustible supplies, principally as mag-

nesium chloride or as the carbonate in dolomitic limestone and magnesite. While the supplies of chloride are adequate for many years, modifications can be made in existing processes for economical production from the latter two materials.

Successful applications as structural materials have been due to the development of alloys specifically adapted to the usual fabrication processes, including sand casting, permanent mold casting, pressure die casting, forging, extrusion, and rolling. The principal alloying elements are aluminum, zinc and manganese, in varying amounts but never exceeding a total of 12%. Many other elements alloy with magnesium but, in general, do not result in useful properties. The composition, properties, and characteristics of the more common alloys are given in the large table.

Sand Castings have been used in this country for about 15 years. They now constitute the largest item in present-day production. The aircraft industry was one of the first to use them and today uses considerably more than half of the output of the several foundries making them.

Sand casting of magnesium alloys differs in some details from the practice used for other metals. Gann and Brooks have

Magnesium Sold or Produced, 1938

Item	Pounds
Non-structural products, manufactured:	
Total of wire, ribbon, shavings, powders, etc.	184,223
Structural products, manufactured:	
Castings	1,067,310
Sheet	124,930
Structural shapes, rods and tubing	80,206
Forgings	5,924
Total products	1,462,593
Total magnesium sales (includes exports and all other uses)	4,819,617

described the various processes in detail in *Transactions* of the American Foundrymen's Association for June 1936, and this article may be briefly summarized here.

Special care must be taken to prevent oxidation during melting and casting. The two principal melting methods are:

1. *Open pot* method uses a large amount of fluid flux at the bottom of a cast steel pot, with a thin flux film on top of the metal. Adequate cleaning of the metal (which is dipped out with hand ladles), good protection, and continuous operation are some advantages of the method.

2. *Crucible melting* uses a small amount (up to 3%) of flux on top of the metal, the flux forming a more or less viscous film which is skimmed back during pouring directly from the crucible.

Designation *(a)*		Nominal Composition *(b*		
Dowmetal	A.S.T.M.	Al	Mn	Oth
E	No. 7	6.0	0.2	..
H	No. 4	6.0	0.2	3.0
J *(c)*	No. 8	6.5	0.2	0.7
L	..	2.5	0.3	3.5
M *(c)*	No. 11	..	1.5	..
O *(c)*	No. 9	8.5	0.2	0.5
P	..	10.0	0.1	1.0
R	No. 13	9.0	0.1	0.6
X *(c)*	..	3.0	0.2	3.0

(a) Most of the compositions liste conform to American Society for Tes ing Materials, U. S. Navy's Bureau o Aeronautics, and Army Air Corps speci fications for magnesium alloys.

Reaction of the molten metal with the air or the moisture in green sand molds is entirely prevented through the use of inhibitors in the sand; sulphur, boric acid, and ammonium fluoride salts are some of the materials used for the purpose. Both natural and synthetic sands are used successfully. Due to the light weight of the metals, high permeability in the sand is desired; it will assist in the venting of gases from the mold. Low density of the metal also necessitates special care in placing gates, chills, and risers. These problems, however, are similar to those arising in any foundry and have always been solved by the application of fundamental principles of metal flow and solidification.

The casting alloy most generally used is Dowmetal H (6.0% Al, 0.2% Mn, 3.0% Zn) as this material offers the best combination of properties and resistance to salt water. While it is used in the as-cast condition for most applications, it can be solution heat treated to increase the toughness and tensile strength. If the highest shock resistance is not important, the yield strength and hardness can be increased also by a low temperature aging treatment. The maximum yield strength, however, is obtained with alloy P (10.0% Al, 0.1% Mn, 1.0% Zn) in the heat treated and aged condition.

The properties of the casting alloys in the various conditions are given in the large table. It will

Composition, Typical Mechanical Properties, and Uses of Magnesium Alloys

Form and Condition	Tensile Strength Psi.	Yield Strength Psi.	Elongation in 2 in.	Brinell Hardness	Endurance Limit, Psi.	Characteristics and Uses	Alloy
Sheet, hard rolled	45,000	34,000	9	70	....	General applications requiring high strength.	E
Sheet, annealed	39,000	20,000	15	57	....	General applications requiring formability.	
As sand cast	27,000	12,000	5	53	10,000	Sand castings requiring good properties and resistance to salt water.	H
Heat treated	38,000	12,000	11	53	10,000		
Heat treated & aged	38,000	18,000	5	70	10,000		
Extruded	43,000	30,000	17	54	17,000	Extruded shapes of improved strengths.	J
Forged	40,000	24,000	10	57	17,000	Good forgeability; medium stressed parts.	
Hammer forged	37,000	26,000	11	51	....	General hammer forgings requirements.	L
Sheet, hard rolled	35,000	27,000	9	53	....	Moderately stressed applications requiring maximum resistance to salt water, and good weldability.	M
Sheet, annealed	33,000	19,000	14	48	....		
Extruded	42,000	27,000	6	42	6,000		
Forged	33,000	19,000	6	43	....		
Extruded	47,000	33,000	11	61	17,000	Highly stressed parts of simple design.	O
Forged and aged	46,000	33,000	6	82	....		
Sand cast, heat treated and aged	36,000	22,000	1	77	8,000	Castings requiring highest yield strength and hardness and not subject to shock.	P
Die cast	33,000	21,000	3	60	....	Standard die casting alloy. Good casting characteristics and high properties.	R
Extruded	42,000	30,000	19	51	18,000	Extruded sections and forgings with best combination of properties and resistance to salt water.	X
Extruded and aged	44,000	34,000	13	54	17,000		
Forged and aged	42,000	28,000	14	62	....		

(b) Magnesium is remainder in each alloy.
(c) Compositions with 0.005% max. iron and 0.005% max. nickel of improved resistance to salt water are designated J-1, M-1, O-1 and X-1.

be noted that they compare favorably with aluminum castings. It is therefore usually possible to cast from patterns originally designed for aluminum alloys without change. In designing magnesium alloy castings, provide generous fillets and avoid sudden changes in section. By eliminating stress concentrations the designer can take advantage of the normally high fatigue endurance of the material. Sections may have to be increased slightly to allow for the lower modulus of elasticity (6,500,000 psi. compared to 10,000,000 for aluminum); this can be done, however, without seriously affecting the weight saving, which still will be at least 25% of the weight in aluminum.

So successful is present-day foundry practice for magnesium alloys that castings weighing more than 300 lb., such as a 5-ft. fan center, are regularly produced. This volume would be equivalent to 450 lb. in aluminum or more than 1200 lb. in cast iron. The majority of castings are, of course, much smaller than this. Aside from aircraft, the principal applications for castings have been in the construction of portable tools, packaging machinery, electric motor fans, motion picture cameras, foundry flasks, bread slicer frames, instruments, aerial cameras, safety blocks, and jigs and fixtures for production machinery in automobile plants.

Landing wheels and engine parts are the principal aircraft applications for magnesium alloy castings at the present time. When correctly designed, the performance of landing wheels has been very satisfactory in all sizes. As military and transport planes have increased in size, the weight savings obtained through their use have become increasingly significant. Magnesium alloy wheel centers have been used successfully in Europe for years, both on the continent and in England, where rough castings up to 200 lb. are not uncommon. A pair of these wheels would result in saving at least 150 lb. in weight, or the equivalent of an additional passenger. While an additional fare cannot be counted on for each trip, it is evident that a large opportunity exists for increased revenue.

In aircraft engines, magnesium castings have been used for years for such parts as accessory cases, blower sections, thrust bearing housings, rear sections, diffuser plates, oil sumps, pump bodies, camshaft housings, air ducts, and for miscellaneous small parts and covers of all kinds. All of the larger engines, both radial and in-line, have such parts. In fact,

the low weight per horsepower of the modern high-output engine would be impossible without magnesium.

In general, the service performance has been good. The few failures which have been experienced usually have been traceable to design. With increasing concentration of power, necessitating high strength steel for the greatly stressed portions of the engine, it is expected that magnesium alloys will find even wider application in accessory parts. Some now used are starters, generators, pumps, de-icing equipment, automatic pilots and other instruments.

Magnesium alloy castings are used to some extent in airplane structures, such as control wheels and levers, tail forks, door frames, air scoops, control housings, pedals, and many miscellaneous brackets and supports. As designing engineers become more familiar with the material and as service experience is gained through present uses, it is probable that more and more castings will be used in these applications.

Permanent mold casting or high pressure die casting should be given consideration when the number of pieces to be made is large enough to warrant the expense of the dies. A considerable number of airplane wheels have been made by semi-permanent mold casting, using sand cores in steel dies. Die casting has been found satisfactory in the production of various engine parts, including rocker box covers and shroud tube fittings. Widespread application of these methods, however, will come only with a large expansion of the aircraft industry as a whole.

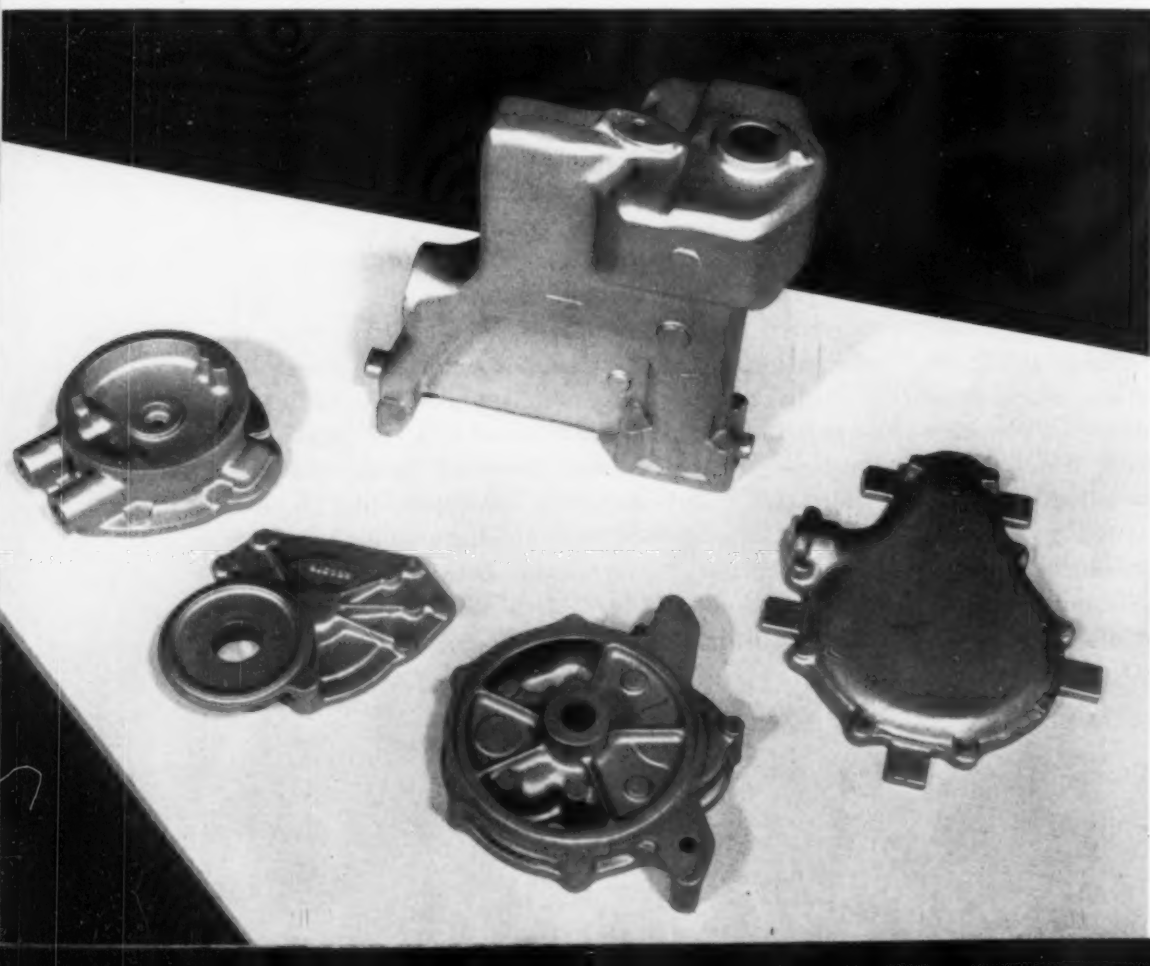
Wrought Forms — The use of wrought alloys has been developing rather slowly, perhaps because these materials have become easily available only recently. At the present time it is possible to obtain extruded structural sections in all forms, such as angles, channels, I-beams, tubing, and bars. The sizes range up to that represented by a 7-in. channel. A number of extrusion alloys have been developed permitting a choice of material for specific applications. The one generally used is Dowmetal X (3.0% Al, 0.2% Mn, 3.0% Zn), as this offers the best combination of mechanical properties and corrosion resistance.

Extruded magnesium alloys are incorporated in much of the furniture and secondary structures of European aircraft. While the logical procedure will be to introduce them by way of lightly stressed parts of the aircraft structure, there are indications that extruded members eventually may be used in primary structures. For example, the main spars of the 12-engined flying-boat, the Do-X, were made of extruded magnesium alloy.

Sheet is used extensively abroad in the construction of aircraft fuel and oil tanks and for furniture, cowling and fairings. These same uses are being developed experimentally at this time in this country but are not yet in widespread commercial production. The possibility of corrosion in gasoline tanks is eliminated by using a cartridge containing inhibitive salts, placed in the sump at the lowest point of the tank.

Magnesium alloy sheet is available here in Dowmetals M and E, of which the compositions and properties are given in the large table, page 239. The M composition (1.5% Mn, 98.5% Mg) possesses the best resistance to salt water and is generally considered to be the most easily fabricated into complex forms such as tanks and cowlings. Alloy E has higher strength and is especially adapted to the lining of baggage compart-

Aircraft Engine Parts, Sand Cast in Magnesium Alloys



ments and to the construction of seats and furniture.

Forgings comprise another class of wrought magnesium alloys. They may be either hammer forgings, for which Dowmetal L is adapted, or press forgings, for which X, J, or O are used. The best properties are obtained in press forgings and these should be used whenever possible. Forgings are not yet used extensively in aircraft construction, although some engine parts have proved very satisfactory.

The most interesting application for magnesium alloy forgings is for propeller blades. Experimental propellers made several years ago did not possess the required properties. The subject has not been forgotten, however, and later work has yielded some encouraging results. In Europe, where more adequate press forging equipment has been available, magnesium alloy propellers are being used with conspicuous success. For example, 26 of the 34 entries in the 1934 European Air Derby used magnesium alloy propellers, including the first six to finish. The properties, given in the following table, of blade forgings made in this country are fully equal to those reported in forgings of European manufacture. Future progress apparently is dependent largely upon the development of the heavy duty presses (12,000 to 15,000 tons capacity) necessary for the larger sizes.

Properties of Dowmetal Propeller Forgings

	Tensile Strength	Yield Strength	Elongation	Endurance Limit
Hub	44,300 psi.	32,500 psi.	10%	....
Taper	46,500	34,500	9	18,500 psi.
Blade	48,600	36,400	5	....
Tip	45,700	32,400	7	....

Fabrication Methods — As with most structural materials, care taken in the small details of working and finishing is essential in the successful application of magnesium alloys. It is possible to comment but briefly here upon some of the features of good shop practice, on which detailed information is available in trade publications.

Magnesium alloys are the easiest of all structural metals to machine. Usually the speed is limited only by that of the available equipment. The ordinary operations are performed dry, a coolant being used only on very high speed screw machine work producing fine shavings or where it is necessary to maintain very precise measurements on large dimensions. Because of the excellent machinability, total manufacturing costs frequently are lower when using magnesium alloys, particularly where the machining expense is a large proportion of the total cost.

The forming of magnesium alloy sheet and shapes can best be done at a temperature of 500 to 700° F. due to a tendency of the material to harden rather rapidly with cold working. A limited amount of cold working is possible, but liberal bend radii should be allowed. Generally speaking, the use of heated tools and dies will permit the forming of parts required in tank and seat construction.

Riveting is the recommended method for the joining of structural assemblies. For this purpose aluminum rivets (2S, 3S and AM55S) are recommended. Design is based on the shearing strength of the rivet material and on the tensile and bearing strengths of the magnesium sheet; the latter may be taken as 60,000 psi., which is about 50% greater than the tensile strength.

Magnesium alloy fuel and oil tanks are possible because the sheet may be welded with the oxy-acetylene flame. While some of the fluxes used for aluminum have been satisfactory, it is best to use the special materials developed for the purpose. The welding rod should be of the same composition as the material being welded. Welds should never be attempted between magnesium alloys and other alloys, such as aluminum, brass, or zinc, due to the formation of brittle inter-metallic compounds. Great care must be exercised to exclude flux from the weld, as any traces of flux occluded or remaining will promote subsequent corrosion. Surface flux is removed by thoroughly scrubbing in hot water, after which the part should be treated in an acid chromate pickling bath which will assist in the complete elimination of the flux and will leave an inhibitive chromate film upon the surface. Further protection should be given through the application of paint coatings.

Protection — Contrary to earlier conceptions, magnesium alloys are quite stable under ordinary conditions of weathering. A buffed or polished surface will gradually tarnish, but roughening or powdering will only take place in areas where heavy industry is located or in regions of continuous high humidity. In salt atmospheres corrosion may be more active and necessitate some form of protection. The material is not recommended for applications involv-

ing direct contact with water or aqueous salt solutions. Recent developments, however, have indicated that the resistance to salt water can be much improved by restricting harmful impurities, principally iron and nickel. As pointed out in the footnote to the large table, each of these is now restricted to a maximum of 0.005% in certain Army Air Corps and Navy aeronautical specifications. While this material is available with some limitations, it is expected that new production methods will permit still greater improvement to be made.

Because of the difficulty of controlling exposure conditions, some form of paint protection should always be applied after the surface has been given a chemical treatment. Several treatments are available at this time, including the "chrome-pickle", "alkaline dichromate" treatments, covered by Bureau of Aeronautics specification M-303a and M382, and the "anodic treatment", covered by the Navy Aeronautical specification PT-13. These methods, as well as our own treatments No. 7 and 8, when properly applied, provide an inhibitive film upon the surface of the metal which promotes lasting adhesion of the paint coatings. Chrome-pickle has the advantage of economy and ease of application, but is not as well adapted for the treatment of machined surfaces as the other treatments, which do not significantly affect the dimensions of the part.

The most satisfactory paint schedule for aircraft consists of one coat of zinc chromate primer and three coats of synthetic resin varnish containing 1.5 lb. of aluminum powder per gallon. Materials meeting Navy Aeronautical and Army Air Corps specifications should be used. Reference also should be made to the finishing procedures covered in Navy Aeronautical specifications SR15 and SR75. Recommended colored finishes are the synthetic resin enamels covered by Navy specifications. The statement is sometimes made that the weight saving of magnesium over aluminum is lost by the application of several coats of paint. In the great majority of cases this idea is erroneous and is only true on very thin sections and sheets, below 0.010 in. thick.

In building assemblies from magnesium alloys which will be exposed to the weather, care should be taken to avoid pockets which might entrap water and ultimately cause corrosion. Enclosed areas should be given at least one coat of primer and should either be made absolutely water tight or provided with adequate drainage and good ventilation. In aircraft applications faying surfaces between magnesium alloy pieces should be primed and allowed to dry before assembly. If subjected to weathering or if other metals will be in contact with the magnesium, additional insulation should be provided with a heavy sealing compound or approved gasket material.

Conclusion — When magnesium alloy parts have been carefully chemically treated and painted, they have given very satisfactory performance, not only inland, but along the seacoast as well. Their logical application would take advantage of the weight saving possibilities as far as is consistent with economy and safety. The performance of airplanes should not be penalized by a concern for what might happen under very abnormal conditions of service; as for instance, the dropping of an airplane into the sea. It is believed that there is a real place for magnesium alloys in the aircraft industry, and that their use after a serious study by engineers and builders will result in increased payloads and improved performance.

LARGE WELDED BRIDGE

Abstracted from The Engineer, *July 14, 1939, page 30*

ONE OF THE MOST IMPORTANT BRIDGES at Paris, carrying an extension of the Champs Elysées across the Seine, has been replaced with a broad structure of which the two important spans are steel arches 220 and 270 ft. long. Use of arch members of uniform depth, hinged at the ends and completely welded of steel plate, is especially notable in view of the importance of the structure to heavy traffic and of the fact that the bridge had to harmonize with the general character of the most attractive thoroughfare leading out of Paris. During the work of reconstruction there was to be no interruption of traffic.

Since the bridge has a deck 115 ft. wide, each span is carried by 12 arches, side by side, spaced about 10 ft. on centers. As described in *The Engineer*, these are curved box girders, uniform in cross-section end to end, 5 ft. deep by 2 ft. broad. Vertical webs are ⅝ in. thick and cover plates ⅞ in. thick. Cover plates do not

(Continued on page 310)

AN IMPROVED BURNER FOR SLOT FURNACES

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INDUSTRIAL fuel engineers have long anticipated the development of simplified burner equipment which would convert an oil fired, slot type forge furnace to one using a better variety of fuel. Experienced men in the gas industry have generally had difficulty in justifying gas as a fuel for forge furnaces, either when comparing the economics of competitive fuels but more especially in view of certain fundamental combustion requirements when heating forging stock to elevated temperatures.

The writers were acquainted with many of the conventional types of burner equipment available on the market in 1936. Premixed gas burners, both high and low pressure, were considered as well as diffusion combustion or luminous flame equipment. Burners considered to represent the best features of each of their respective classes were installed in furnaces at friendly forge shops. For a number of reasons the results obtained failed to fulfill the requirements of our customers.

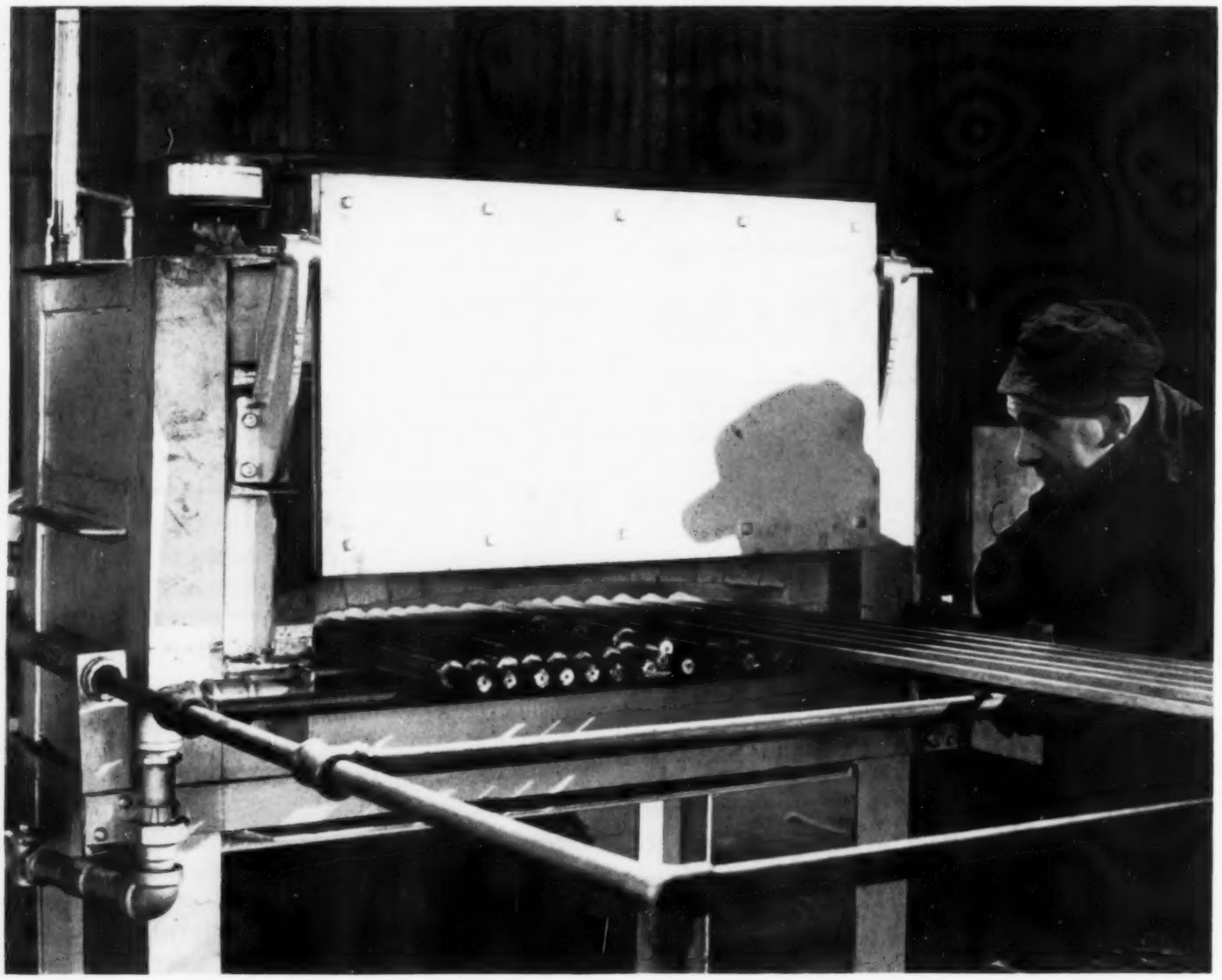
The inspirator gas burners produced a scale that, while relatively thin, was hard and adherent; if this scale was driven into the forgings, imperfect work and decreased die life was the result. When production rates were stepped up, overheating and burnt steel resulted.

The luminous flame eliminated many of the objectionable features of the premixed burner; however, for equivalent hearth areas and combustion space available in standard slot furnaces, production rates decreased and fuel consumption increased. Large hammers commonly carry high burden rates and fixed charges so that, irrespective of relative fuel costs, production rates are necessarily of extreme importance in the selection of heating equipment. The furnace must be capable of delivering properly heated steel as rapidly as the hammers can forge it.

A consideration of an ideal forge furnace emphasizes the following factors:

1. Rate of heating the steel.
2. Uniformity of heating the steel.
3. Character and amount of scale produced.
4. Temperature distribution across slot.
5. Effect on die life and hammer repair.
6. The cost of fuel.

Appreciating these essential requirements, the writers elected to investigate the possibilities of certain observations made during the operation of their earlier installations. A standard 90-in. slot type forge furnace was constructed for experimentation with burner equipment designed either for premix or luminous flame. Such a systematic and comprehensive course of study eventually resulted in the selection of the type of burner equipment now standardized for this variety of heat applications as recom-



mended in all our company's various properties.

In this study of the two methods of gas combustion certain practical observations and conclusions were made. Differences were noted in the velocity of reaction or speed of combustion, intensity of heat liberation, and rate of heat transmission from the flame. The speed of reaction was dependent upon the temperature at which the gases oxidized and upon the concentration of the reacting substances. Premixing of gas and air in near-correct proportions resulted in practically instantaneous combustion, requiring a minimum of combustion space with a maximum intensity of heat liberation; however, convection was the principal means of transferring heat to the work. We had, accordingly, established two desirable combustion characteristics (namely rapid combustion and transfer by convection) at the sacrifice of a third equally as important — that is, heat transfer from the flame to the work by radiation.

The diffusion type of burner gives a high degree of flame luminosity — thus materially bettering the efficiency of heat transmission of flame to work — accompanied, however, with a greatly reduced speed of combustion, thus necessitating large furnace areas for equivalent heat inputs. A review of the fundamental principles of luminous flame combustion indicated that the flame luminosity was dependent upon the number of carbon particles set free when the hydrocarbon dissociated. In the presence of insufficient quantities of air, and at temperatures in excess of 1830° F., methane, the principal constituent of natural gas, breaks down into free carbon and liberates hydrogen. This reaction is endothermic, requiring approximately 70,000 B.t.u. per pound-mol from external sources. Of importance in the final design of the selected burner equipment was the fact that the heavier hydrocarbons, such as those commonly found in fuel oils, break down

more readily and require considerably less heat to carry on the process.

At this point in the experimental study, neither the straight inspirator non-luminous flame nor the highly luminous diffusion flame appeared to meet the requirements of forge shops, as previously established. Actual tests later substantiated these observations. Numerous efforts were then made to devise conditions which would retain those desirable characteristics of premixed combustion and at the same time incorporate the advantages of the radiant flame. Eventually the combination gas-oil burner was selected as giving most nearly the combustion characteristics believed essential.

With conventional oil burners, the fuel must first be atomized, then vaporized or gasified, after which it "cracks" or is broken down chemically to form free incandescent carbon.

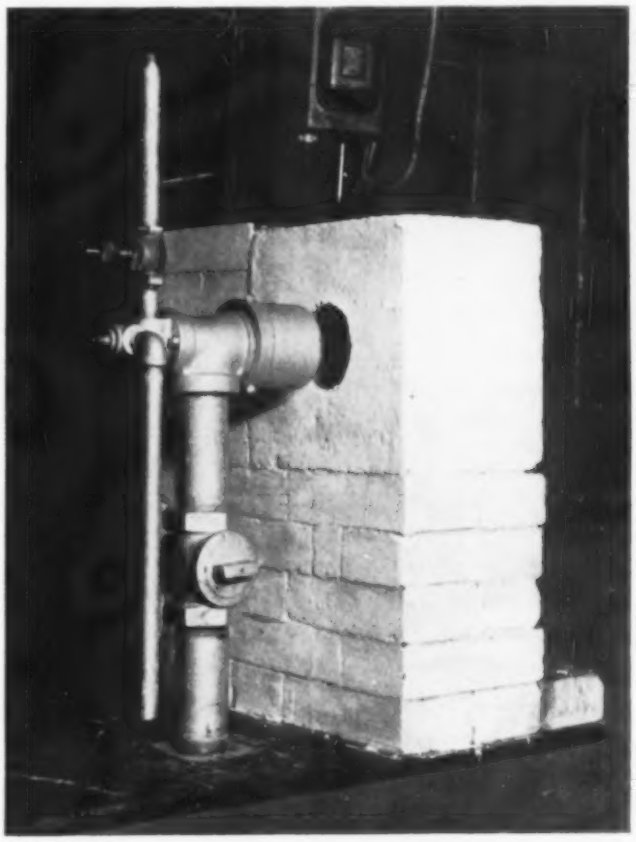
Initial burning of part of the gaseous vapor supplies heat to gasify more oil and to crack or break down the oil already gasified. Both these latter reactions are endothermic (require heat) so that instead of liberating the full heat content of the oil and producing rapid combustion of high intensity, a part of the heat supplied by the initial combustion is absorbed, reducing the flame temperature and the rate of combustion. This in turn prevents prompt gasification, cracking of the oil vapor, and combustion of the free carbon; as a result these reactions continue as the gases travel through the furnace and as they are discharged in a voluminous, extremely hot and frequently smoky flame from the working opening of the furnace.

Operation of the conventional oil burner therefore depends upon the initial gasification and combustion of a part of the oil fuel to promote its complete gasification and combustion. Because of the limitations of the entire process, the nature of the burner and the chemistry of combustion, this initial gasification and combustion is limited and uncontrollable.

The gas-oil burner, as perfected, burns some gas with the fuel oil. Approximately 70% of the heat input to the furnace is supplied in the form of gas. The heavy hydrocarbons of the oil are surrounded by an intimate mixture of burning gas and air, which furnishes adequate heat for cracking the oil molecules and raising the carbon particles to incandescence. Turbulence, a feature to be avoided in luminous gas flames, probably accelerates the decomposition of oil molecules in the gas-oil flame.

Gas, with its inherent rapid combustion and high flame temperature, accelerates the vaporization, cracking and combustion of the oil, with the result that combustion is completed within the furnace. This produces maximum flame radiation and heating rates with minimum furnace temperature. Less flame issues from the furnace and smoke and soot are eliminated.

The burner is designed for simple construction and easy accessibility of all integral parts. Illuminating hydrocarbons in the form of fuel oil enter at, say, 5 lb. pressure through a single fixed orifice of sufficient size to reduce oil fluctuations to a minimum. High pressure gas is introduced through an annular opening entirely surrounding the oil spray, effectively atomizing even heavy grades of oil. Burner blocks are shaped for high efficiency entrainment of secondary air, thereby stepping up the capacity of the burner as well as assisting in establishing the desired flame characteristics. Oil is regulated by a single 3/8-in. special V-opening valve. Primary air supply is controlled with a 2-in.



Assembly of New Gas-Oil Burner. From below come air through the 2-in. line and oil through the 1/2-in. line. From above comes gas through a 3/4-in. pipe. Burner block, 13 in. square, is built into the furnace lining

slide gate valve located adjacent to each burner.

Natural gas is available in Central Indiana at 25-lb. gage pressure; consequently the design may use the kinetic energy of the gas stream. Primary air for combustion is delivered at approximately 12 oz. pressure at the burner. Fuel oil available ranged from 10 to 12° Bé.; consequently the burner provided for continuity of flow when using heavy oils at low rates of flow. The size burner most commonly used has a 2-in. air connection with ½-in. gas and oil connections and is capable of passing as much as 1200 cu.ft. natural gas plus 4 gal. oil per hr.

These burners are located on forge furnaces in the conventional manner, one burner on each side, staggered with a minimum distance of 10 in. between center lines (preferably 12 in. where conditions permit). The burner block, with conical opening flaring open toward the center of the furnace, is set in the wall just under the skew-back, and the burner centered with the opening with its nozzle $1 \pm \frac{1}{4}$ in. from the outer face of the burner block.

Its operation is simple. The gas pilots are lit and the burners are started and the furnace heated to about 1600° F. with gas only, proportioning the air and gas by means of the dial gas cock and air blast gate at each burner. The supply of air is then increased and the oil is turned on sufficiently to give the fuel input and flame character required for operation. The gas pilots may then be turned off. The gas input is constant, oil and air being adjusted to meet either idling or operating conditions.

This burner is not a combination gas and oil burner, but a unit engineered for the simultaneous use of two fuels to secure the advantages of both without the disadvantages of either. However, the burner may be used for straight oil firing. The capacity of the burner is somewhat too small for reaching forging heat when using gas alone.

Operating experiences indicate that this gas-oil burner will materially increase forge shop production over that formerly obtained when firing with oil alone. This is particularly significant in view of the fact that the original oil fired slot furnaces heated stock at higher rates than any of the gas fired units first tried. A comparison of operating results has evaluated the following advantages:

1. Furnace lining life increased 300%. Linings of furnaces fired with conventional oil burners usually require replacing every three months. Furnaces equipped with gas-oil burners need to be relined every nine months.

2. Fuel saving 12 to 20%. Furnaces fired with conventional oil burners require 4,500,000 B.t.u. per ton finished forgings. Furnaces fired with gas-oil burners require 3,600,000 B.t.u.

3. Die life increased 15 to 22%.

4. Die clean-up decreased 50%.

5. Scale decreased. Decrease in scaling has been remarkable, although no actual comparative figures are available.

6. Cleaner forge shop and better working conditions. Furnaces are quickly heated from cold without smoke, as gas only is used during heating-up period.

7. Minimum flame from slot and flues.

8. Simplicity of application. Burners are readily installed on existing forges without expensive changes; it is only necessary to install the burner block in the lining and attach burner to furnace casing with a bracket.

9. Lower power consumption and maintenance. As only 5-lb. oil is required at the burner, the lower operating pressure decreases maintenance on the fuel pump and decreases power consumption.

10. Production rates increased 15 to 25%.

Successful applications have been made to the following sizes of slot type furnaces:

Width	Depth	Hearth Area	Height To Skew	Slot Height
44 in.	22 in.	6.7 sq.ft.	20 in.	3 in.
48	24	8.0	20	4
72	34	17.0	22	5
86	34	20.3	22	5

Assuming a typical case and the advantages listed above, the final table illustrates a breakdown of anticipated operating savings due to this type of heating equipment. The analysis is based upon a production of eight tons of finished forgings per 16-hr. day.

Table of Operating Costs

Item	Cost With Oil	Cost With Gas-Oil	Savings per Ton
Die cost	\$4.00	\$3.20	\$0.80
Clean up dies			
Labor	0.14	0.07	0.07
Burden	0.35	0.18	0.17
Furnace repairs	0.40	0.20	0.20
Production burden	8.00	6.67 *(a)*	1.33
Fuel cost	3.00	2.64	0.36
	Total savings per ton		\$2.93

(a) 20% increased rate of production at \$4.00 per hr. burden rate.

MANUFACTURE OF CEMENTED CARBIDES

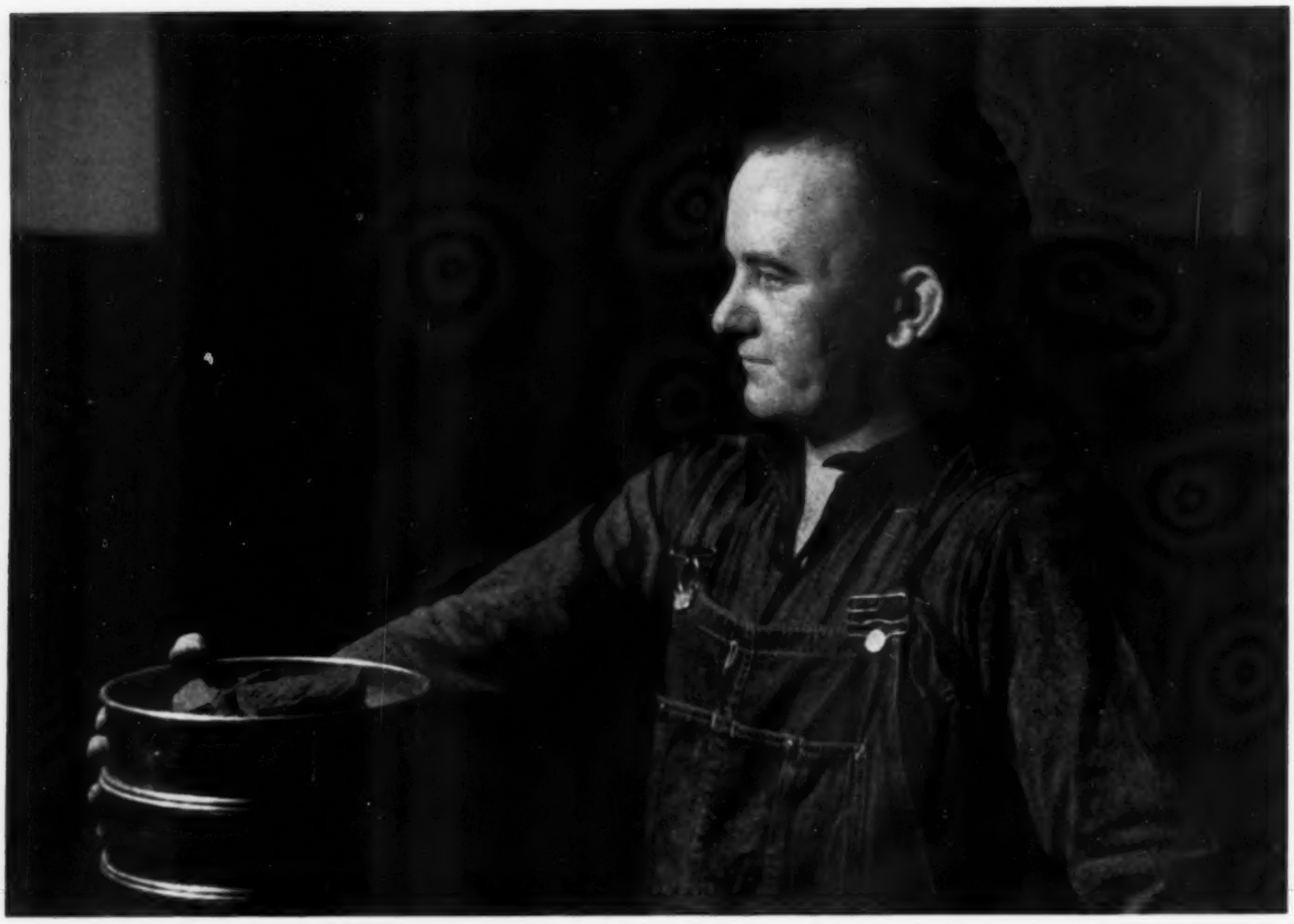
Pictorial Story Made
at Plant of
Carboloy Company, Inc.
By Van Fisher

*S*UPER-HARD cutting and wearing materials, so-called cemented tungsten, titanium and tantalum carbides, are the product of ultra-modern powder metallurgy. The rare metals used are highly purified chemically to their oxides or ammonium salts, having the texture of brown sugar. These compounds are reduced by hydrogen to metal powders, and after compounding, compacting and processing, are ready for the consumer in accurately shaped, small objects, ready to be brazed into steel holders for duty.

UNIFORMITY of working in process, uniformity of shrinkage during pressing and sintering, uniformity of density, strength and hardness at the finish all depend on uniform chemical purity and controlled grain size distribution at various stages of the manufacture. An almost inordinate amount of screening, mixing and blending is necessary before a start can even be made. For instance, tungsten powder is being screened in the nest of sieves of graded mesh at left; they are given a rapid circular motion and tapped every second by the hammer above.

Eventually a large can of tungsten powder of sharply limited grain size is dumped into this mixer with a weighed amount of carbon powder and thoroughly stirred. The correct amount of tantalum oxide and titanium oxide is also added at this point, according to formulae gained by experience, to adapt the finished product best to specific use.

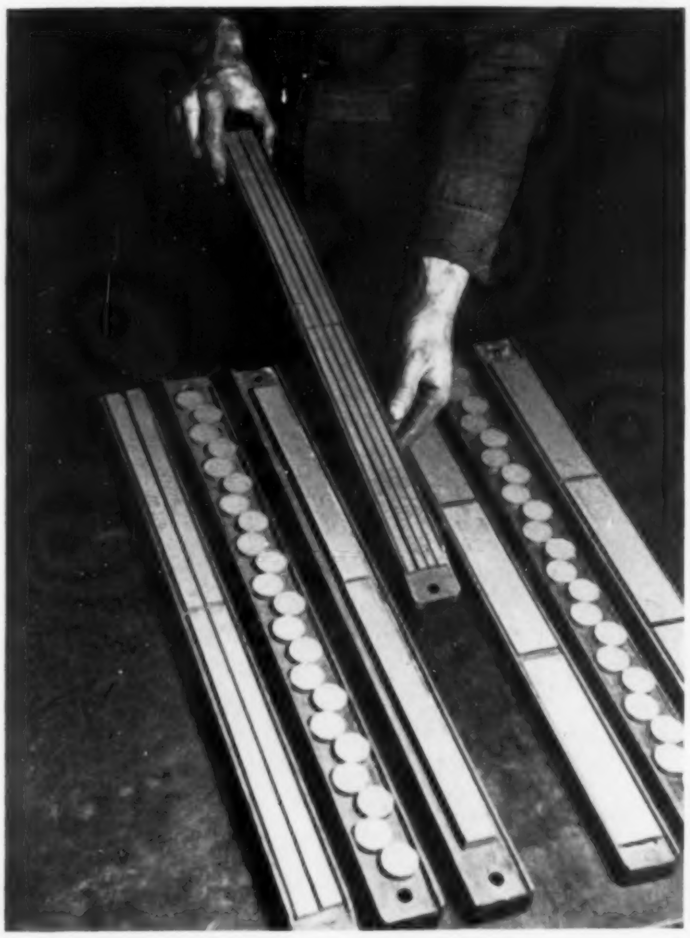
Loosely compacted bricks of the tungsten-carbon mixture are then pressed, placed in graphite boats and started through a wire-wound, electrically heated tube furnace. Temperature and time are adjusted, in general, according to the grain size of the metal powders — a fine particle, once at heat, can be converted completely to carbide more quickly than a coarse one. Dry hydrogen is the atmosphere; this not only protects the furnace windings up to 2400° C., but reduces the titanium and tantalum oxides in the mixture, reacts with atmospheric oxygen trapped within the brick and boat, and thus preserves the carbon to its real job of joining chemically into a metal carbide. The boat and its contents cool in hydrogen while still protected by a water-cooled prolongation of the muffle.



The fully carburized blocks are quite friable and pulverize during the gyrations and bumping of the nest of screens. Usable particle sizes vary according to the final properties desired, but the maximum is about 15 microns or 0.006 in. diameter. Cobalt metal powder is then added in correct quantity from 5 to 30%; the greater the amount the stronger and tougher the final object, but the hardness is slightly less. Weighed amounts are mixed with spatula and charged into a ball mill, which is a steel can containing hard iron balls of assorted sizes. These mills are rolled over and over for hours, even days, and the ball action smears completely every particle of hard carbide with a thin layer of ductile cobalt. After another screening, a little paraffin for pressing lubricant is mixed in a pug mill and the powder, after a careful check-up on distribution of particle sizes, is ready for compacting.

This carefully prepared powder is then pressed into small bars, slabs or shapes under pressures up to 30 tons per sq.in. The "old standard" method is indicated above. A correct portion of powder is weighed and then poured into an open mold of hardened and ground steel. (The mold is shown disassembled; one side and two end blocks are set to the left of the base, and the top and other side are set to the right.) The loose powder is leveled off with the gage, the top lowered on, and the assembly slipped into the hydraulic press. First the side jaws grip the mold tightly, then the ram descends to compact the powder for a second or two. This compacted bar has strength and coherence about equal to a soda cracker.

Such bars are later to be cut into usable shapes. To supply the new trends for large numbers of standard shapes, the "pill machine" is suitable. It automatically fills the mold through a swinging funnel, then the upper ram compacts the powder, and the shape is ejected by raising the bottom of the mold. Such machines are good for pellets, eyelets, rings, cylinders and such symmetrical shapes.



Bars or "ingots" up to a foot long, $1\frac{1}{2}$ in. wide and $1\frac{1}{2}$ in. thick, die nibs (rings or cylinders up to 4 in. dia. and 3 in. thick), wafers and eyelets as small as $\frac{1}{4}$ in. dia., are then placed on graphite slabs and passed through a pre-sintering heat at about 1550° F. As shown below, the furnace has an air lock at the entrance (and the exit) and is quite similar to the carburizing furnace. A protective atmosphere (principally hydrogen) prevents any chemical change; the aim is to lightly weld the contacting hard particles, or rather their coating of cobalt, at billions of points, and give the compacts a strength and consistency of chalk. In this form they are readily machinable, yet not too fragile.

Pre-sintered Carboloy may be readily cut by thin rubber wheels, and machined into all variety of shapes on standard lathes, milling machines and gear cutters. Sizes are carefully adjusted for a large shrinkage during final furnacing — 15% linear or about 1/3 in volume. Due to care in getting homogeneous mixes, this shrinkage is surprisingly uniform, flat surfaces, sharp edges and corners retaining their form without warpage or dulling. Packed on corundum sand in a covered graphite boat, final sintering is done in hydrogen atmosphere at 2600 to 2800° F., the time and temperature depending on composition of the parts and their mass.

The view below shows a furnace man pushing a boat load of pre-sintered parts into the open end of the furnace for final sintering. Gear reducer on the pusher mechanism is shown in foreground.

Most shipments are made by air mail! These parts, worth about 50¢ a gram, are to be attached or embedded in steel members by a brazing or hot sinking operation. Any change in shape of cemented tungsten carbide must be done by grinding; its hardness exceeds that of any metallic tool. Principal uses are for cutting edges on all varieties of tools for machining metals and for dies to draw wire, tubing, and bars. Growing uses are for wear resisting parts where unsatisfactory operation would follow infinitesimal wear, or where replacement would be costly, either in mechanic's labor or in productive time.

WILM'S PIONEER INVESTIGATIONS ON DURALUMIN

By Louis W. Kempf
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EDITOR'S NOTE — A three-session symposium on the subject of precipitation hardening will feature the program of the Chicago convention of the ⊕, next month. Since this branch of general metallurgy has originated from specialized work on the hardening and strengthening of aluminum, it seemed appropriate to print in METAL PROGRESS a translation of the first technical description by Wilm of the strong aluminum alloys he invented. This translation, by the way, was made a long time ago by Aluminum Research Laboratories. Mr. Kempf also responded to a suggestion that he write us an appraisal of Wilm's original work, in the light of the intervening developments. Much of the biographical material is taken from an article appearing in *Aluminium*, Vol. 17, 1935, p. 502.

Commentary on the Work of Alfred Wilm

THE ARTIST in painting, sculpture, architecture, or other of the fine arts has no small degree of satisfaction in knowing that his masterpiece, if sufficiently worthy, may be preserved precisely as it left his hands for generations or centuries. However it is seldom granted to the worker in the industrial arts to see his creations survive without modification for more than a few years. This is the price of progress, and few are those who would have it different.

It is worth remarking, therefore, when a worker in these fields not only builds so finely that his creation endures throughout his lifetime and is utilized today in precisely the form in which it was evolved, but also founds by his creative acts an entirely new field of metallurgical endeavor. Such a one was Alfred Wilm. His physical creation was the alloy now known commercially as "duralumin", and the new field of metallurgy which he opened is that of solid solution and precipitation hardening.

Alfred Wilm was born in Silesia, southeastern Germany, in 1869. His father was one of the landed gentry, and Wilm became interested in chemistry during attendance at an agricultural school. This interest in chemistry led him to continue in advanced studies and subsequently he went to the University of Göttingen as assistant in chemistry. Wilm then spent about four years in the Goldschmidt chemical factories, and it was here that he first became interested in the metal, aluminum, which was used in considerable quantities for the Goldschmidt process for the thermal reduction of metallic oxides.

In the spring of 1901, at the age of 32, Wilm became metallurgist for the Zentralstelle für Wissenschaftlich-technische Untersuchungen in Neubabelsberg, near Berlin. This was a governmental research organization for the investigation of military materials, and he studied the problem of increasing the strength of aluminum. Regarding this phase of his endeavors, Wilm states:

"Two full years went by during which I investigated all kinds of additions without achieving the desired strength, until the aluminum-mag-

nesium alloy with copper and manganese led to the desired goal because of its peculiar aging characteristics after heat treatment. Although the discovery of the aging effect after heat treatment of magnesium-bearing aluminum alloys took place in the autumn of 1906, I still needed two full years to determine the conditions under which I could be sure of obtaining the maximum tensile properties. I had to know precisely what difficulties I might expect to encounter as a result of variations from the prescribed conditions which would occur in plant practice."

What appears to be the earliest public record of this work is German patent No. 170,085. This patent bears the filing date of October 20, 1903, and the issuance date, May 9, 1906. It covers the process of improving aluminum alloys, specifically aluminum-copper alloys, by heating to elevated temperatures and rapidly cooling to ordinary temperatures. The elevated temperatures recommended by Wilm were in the range 900 to 1000° F., plus or minus 50°. He recognized quite distinctly the necessity for increasing the heat treating temperature with the copper concentration.

Illustrative alloys cited in this patent refer to an increase in the strength of a "chill casting" of 4% copper, balance aluminum, from about 22,000 psi. tensile strength and 5% elongation in the as-cast condition to about 32,000 psi. and 7% elongation after the new heat treatment. Another illustration gave 39,500 psi. tensile strength with 17.3% elongation for a 4% copper alloy in the rolled and heat treated condition. (The latter figures compare favorably with those given in the National Metals Handbook in the data sheet on "The Properties of Aluminum-Copper Alloys", page 1248. Here the properties of a wrought 4% copper alloy in a similar condition are given as 40,000 psi. tensile strength with about 30% elongation.)

This 1903 discovery of a method of hardening non-ferrous alloys by solution heat treatment is probably just as fundamental as Wilm's subsequent discovery of the precipitation hardening effect in aluminum-copper-magnesium alloys after aging, yet it is the latter which received the greater part of his attention.

Alfred Wilm; 1869-1938
Inventor of duralumin; discoverer of solution heat treatment and aging (precipitation hardening)

Apparently the earliest publication describing the room temperature aging effect following a solution treatment in aluminum-copper-magnesium alloys with or without manganese is that appearing in *Metallurgie*, April 22, 1911, although German patent No. 244,554 describing the effect was filed March 20, 1909. This patent was issued on March 9, 1912. A translation of the article in *Metallurgie* is on page 259.

The principal alloy described in this article contains 3.5% copper, 0.5% magnesium, balance aluminum, while the properties of a similar alloy containing apparently 4% copper, 0.5% magnesium, and 0.6% manganese are described in a subsequent article in the *Kriegs-technische Zeitschrift* in 1913, No. 3, page 97.

The curves of Fig. 337 (page 260) typify hundreds which have been made since, determining the optimum solution heat treating temperature for the alloy being investigated. It is clear from the curves that any temperature in the range 470 to 540° C. (880 to 1000° F.) is satisfactory for the solution treatment of a 3.5% copper, 0.5% magnesium alloy. The curve of Fig. 335 will be readily recognized as typical "precipitation hardening", the hardness increasing from 70 after quenching to about 100 after 20 hr. at room temperature.

Most of the other data have to do with the cold working of the alloy subsequent to heat treatment, and are of less interest than these typical curves showing solution hardening and precipitation hardening. Nevertheless, even in the matter of cold working, Wilm demonstrates one additional very important principle — that is, that cold working of this type of alloy following heat treatment should, for maximum effect, be delayed until the hardening at room temperature is substantially complete.

It is interesting to follow, through the publications mentioned, the course of Wilm's development of the composition now known as

duralumin, containing about 4% copper, 0.5% magnesium, and 0.5% manganese. The alloy of earliest record containing only 4% copper was reported to develop (in the wrought form after solution heat treatment and rapid cooling) a tensile strength of 39,500 psi. with 17% elongation. Subsequent publications give 45,000 psi. and 16% as the properties obtainable with an alloy containing manganese as well as copper, and 52,600 psi. with 22% elongation for an alloy with 4% copper and 0.5% magnesium. Finally, 65,400 psi. and 17.5% elongation are given for an alloy with copper, magnesium, and manganese.

In the autumn of 1908, the preparatory work had advanced to the stage where the Wilm alloys could be introduced into regular commercial production. Unfortunately at this time a change took place in the management of the Zentralstelle. Doctor Stribeck had been director of the laboratories during these seven years of developmental work and undoubtedly a great deal of credit is due him for his sympathetic and encouraging attitude. The new director was definitely less favorably inclined, and we find that Wilm soon resigned. There then followed about a year of struggling with bureaucratic red tape before he succeeded in purchasing the patent rights of the alloys which he had developed. Rasmus Beck, technical director of Dürener Metallwerke, had previously become interested in the Wilm alloys and had negotiated for production rights. The final arrangement was that Wilm was allowed to purchase the entire rights upon agreeing to license Dürener for the exclusive right to manufacture in Germany. "Duralumin" was coined from "Dürener" and "aluminum".

Wilm was never much in favor of patent publications; some of his remarks along this line are interesting:

"The secret of the aging of aluminum alloys containing a small amount of magnesium, by simple storage after heating to a definite temperature, was unknown in the technical world. The competitors might have investigated the alloy chemically in all directions. If they were fortunate, they would have found the 0.5% of magnesium (since with 4% copper and 0.6% manganese, the alloy would not bear more than 0.5% magnesium and otherwise rolling would have become impossible) and 0.5% magnesium is difficult to find analytically in the presence of an excess of aluminum. . . . . Furthermore, unless one followed the exact directions for heating the alloy in a fused salt bath, in which alone the temperature is uniform, it showed no higher strengths than other alloys. In practice, muffle furnaces were also used to heat the articles during fabrication. The tensile strength might just as well have been determined by shaking dice, since the temperatures in the muffles were too variable, and electrically heated muffles had not yet been introduced.

"However, the patent law requires that the invention shall be so clearly described that any person who desires to do so may test the invention. If I had said nothing about aging, and the subsequent testing had shown lower strengths than I stated, the patent would have been declared void. Later, when the patent was issued, what expenditures of time and money, what legal activity was devoted to defending the patent against all attack! Like a mutiny, people threw themselves upon the patents. It hailed suits for invalidation and for shop rights by the dozen. The first act would be in the Patent Office, the second act in the Court of Appeals, and the third act in the Supreme Court at Leipzig. When these attacks failed, the drama repeated itself from other angles, and passed a second time through these three stages."

Wilm became connected in a technical capacity with the Dürener Metallwerke in 1910, and devoted the next four years to the problems of exploitation and commercial production of his alloy. He is reported to have served his country well during the War. At its end he said: "The war was ended. Germany lay fettered on the ground. General interest centered upon providing food for the people; therefore, I answered this call, feeling some hereditary responsibility, and entered the agricultural service of the country." He returned to the land and developed a large chicken farm which became important in the locality as a scientific breeding place for pedigreed poultry.

Wilm never amassed wealth. As a typical man of science, he was anything but a good business man. His business associates profited by sub-licensing his inventions while he himself received just enough to satisfy his modest desires. He died on August 8, 1938.

His metallugrical masterpiece, however, endures as an important part of the current industrial production of heat treated, wrought aluminum alloys. It has been necessary for industry to devote an enormous amount of energy to discover the optimum fabrication and application details for these alloys, and a great deal of credit is due many workers in the commercial development. Nevertheless, Alfred Wilm built well; his creation will aways stand among masterpieces of metallurgical art.

PHYSICO-METALLURGICAL INVESTIGATIONS ON

ALUMINUM ALLOYS CONTAINING MAGNESIUM

By Alfred Wilm
Ober-Ingenieur, Schlachtensee, near Berlin

Translated from **Metallurgie**, *Vol. 8, pages 223 to 227, April 22, 1911*

THE TRANSFORMATIONS which steel undergoes during the hardening process are clearly pictured by the microscopic investigations of steels containing carbon. Just as carbon in iron gives it the peculiar property of being hardened by heating and quenching, so this peculiarity is also common to aluminum; however, the hardenability in this case does not depend upon the presence of carbon, but upon that of another light metal, namely, magnesium.

My investigations on aluminum alloys, which I have carried on since the year 1903 at the Headquarters for Scientific and Technical Research, Neubabelsberg, have shown that a small magnesium content in aluminum makes the latter capable of being hardened by means of a heating process. Micrographic investigations, however, have not sufficed to give me any information as to whether any structural changes take place during this hardening process. Perhaps others will be able to represent by crystallographic pictures these peculiar phenomena which the aluminum-magnesium alloys show. Since no appreciable changes in form accompany the very considerable changes in properties, I can only discuss here the effect of the hardening process on aluminum alloys containing magnesium, without being able to give information as to the mechanism of the thing itself. (Accurate measurements on cylinders showed that with a measured length of 50 mm. the length had increased about 0.006 mm. immediately after the hardening process, but this increase in length disappeared after a few days.)

The hardening process in aluminum alloys takes place in quite a different way than in steels containing carbon. If the latter, in order to harden them, are brought to a suitable temperature and then quenched, they have their characteristic hardness immediately after quenching. The aluminum alloys containing magnesium, on the contrary, are soft immediately after quenching; however, after a few hours an increase in hardness begins, which is very considerable in the first few hours and gradually becomes slower in subsequent hours. Figure 335 shows this phenomenon. Even a small addition of about 0.5% magnesium to aluminum acts in the manner just described. The hardness thus produced is, however, still very small as compared to that of other bronzes. The simultaneous presence of copper has a very important effect in increasing both the hardness and the other properties which depend upon the strength. Upon studying the photomicrograph of an aluminum-copper alloy containing magnesium, immediately after casting, one notes in it various dark veins. If the alloy is then heated at about 500° C. and quenched in water, the picture shows a more homogeneous composition. This, however, is the same immediately after the heat treatment as it is

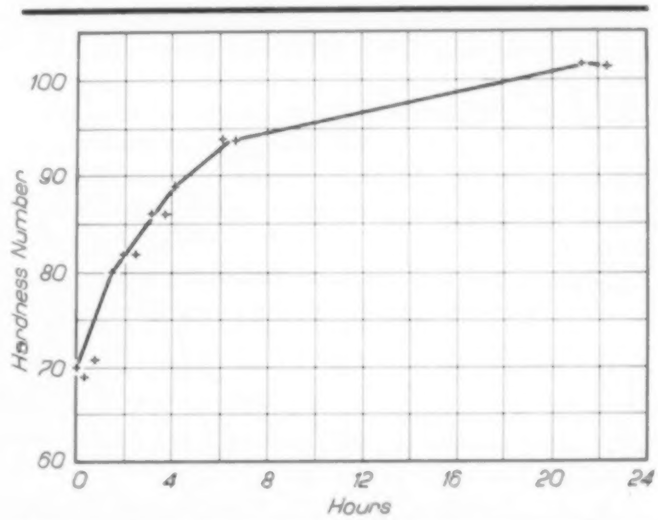


Fig. 335 — [Hardening of Alloy on Aging]

after several days, in spite of the fact that the properties have changed considerably.

The hardening process in carbon steels has this in common with the aluminum alloys containing magnesium — that neither hot working nor cold working is able to give to the material the

strength and elongation in a tensile test that can be had after the hardening process.

The temperature usually used for hot working of aluminum and its alloys is about 400° C. At this temperature aluminum can be very easily brought into any desired form by forging, or pressing and rolling. If the material has been given a preliminary form by such operation, and it is desired to make it still denser by subsequent cold working, especially in order to raise the elastic limit of the material as high as possible, it is heated again at about 400° in order to make it more amenable to the cold working. Whether now a cold working takes place immediately after the annealing or not until several days later, the properties which have been given to the material by annealing at this temperature do not change on storage. We obtain by cold working the tensile properties shown in curve *a*, Fig. 336. In this case a 7-mm. sheet was used, containing 3.5% copper, 0.5% magnesium, and remainder aluminum, and was rolled down by steps to 2 mm., samples of the sheet being taken in the meantime. Naturally the elongation has decreased during the cold working, while the strength and hardness have increased. The values for elongation have been written on the curves in numbers for the sake of simplicity. If now the samples from all stages of the rolling are heated at 500° C., quenched in water and stored about four days, all of the sheets develop the tensile

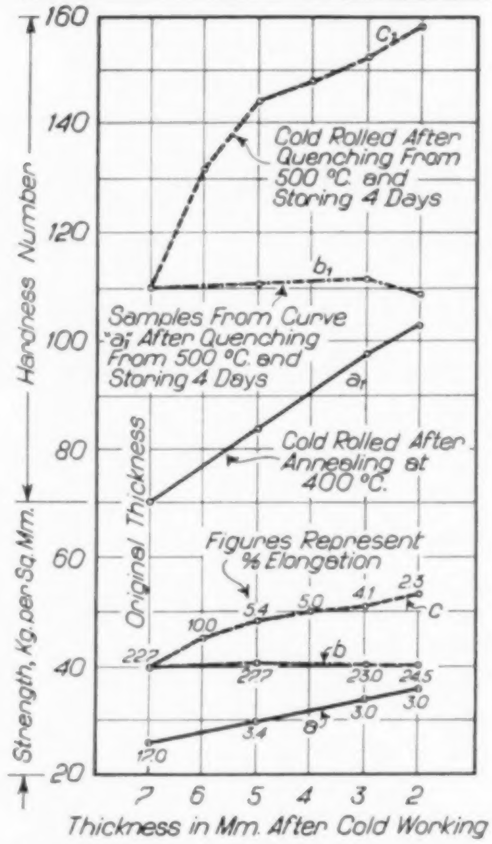


Fig. 336 — [Effect of Cold Working on Strength — Curves a, b and c — and Hardness — Curves a_1, b_1 and c_1 — of Al-Cu-Mg Alloy]

properties shown in curve *b*, Fig. 336. Here, also, the values for elongation are written in numbers on the line. From this it is seen that the hardening process in the case of aluminum alloys containing magnesium differs appreciably from that of steel. While the steel loses by the hardening process still more of the elongation which it previously had, the aluminum alloy with its increase in hardness and strength has also increased in elongation. Thus, there is given to magnesium-bearing aluminum alloys, in contrast to steel, the property of being amenable to further cold working after the hardening process. If one proceeds in this manner the curve *c* is a result.

As appears from what has been said, the effect of heat treatment is dependent on the heating temperature employed, as in the case of steel. In order to get a picture of how the hardness produced by heating and quenching with subsequent storage rises with the heating temperature employed, Fig. 337 may be observed. It is indeed certainly to be assumed that even below 400° there will occur a small increase of hardness on storing (aging); nevertheless, this increase is so very small that it has no practical importance. For the working of the material, it is in fact very important to avoid increasing the hardness in the course of annealing the material during the process of working; since, although the elongation values are very considerable after the heat treatment, the material is nevertheless more easily worked in the cold state if, for the purposes of cold working, lower annealing temperatures are used (as, for example, in the drawing of wire). One will therefore in practice use the heat treatment only after working has been completed, or when special properties such as high elastic limit and hardness

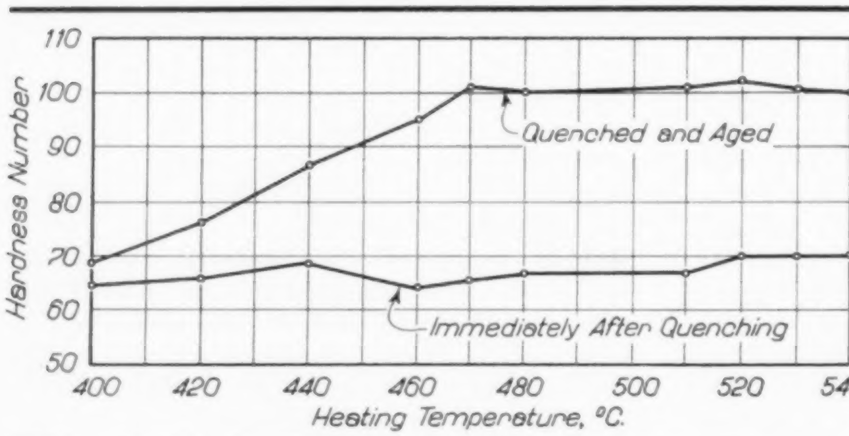


Fig. 337 — [Hardening by Aging Varies in Intensity With Temperature of Prior Solution Treatment, up to a Certain Degree]

Fig. 338 I Fig. 338 II Fig. 338 III Fig. 340

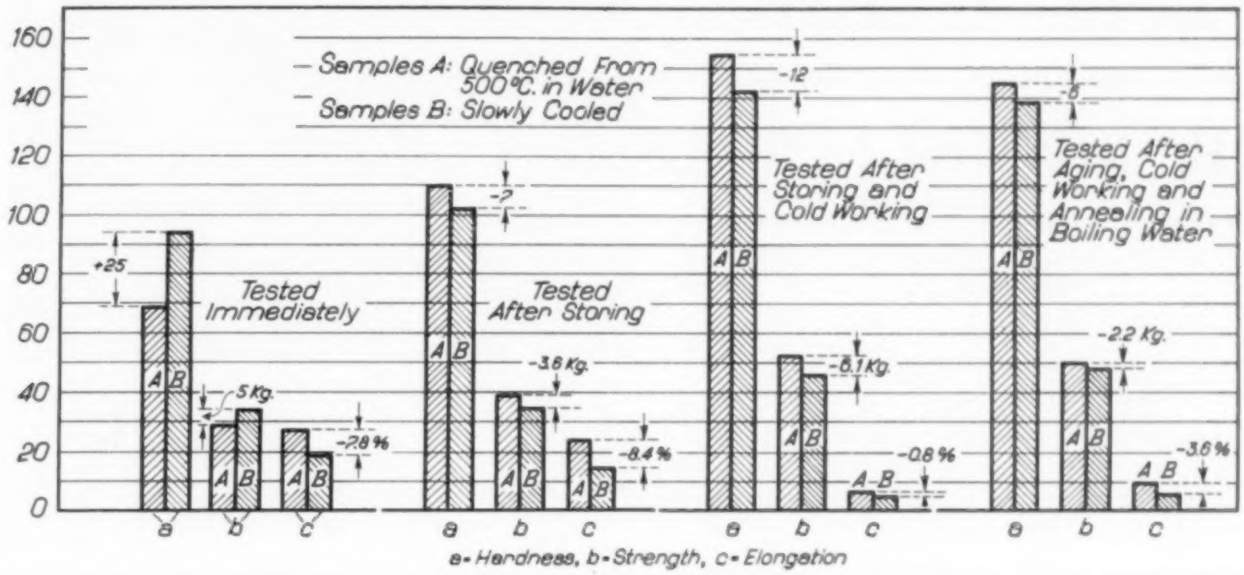


Fig. 338 I, II and III — [Quenching Rather Than Slow Cooling From Solution Treatment at 500° C. Improves Ability to Strengthen by Aging Without or With Cold Work]. Fig. 340 (left group of pylons) [Elongation Is Improved by Accelerated Aging or Tempering at 100° C.]

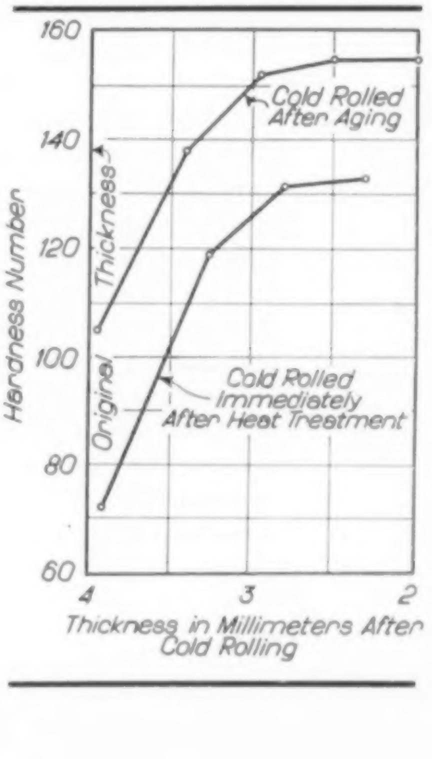
but lower elongation are required. In this case, another slight cold working follows after the heat treatment and aging.

The demands which present practice makes on the tensile properties of light metals are so great that one must obtain the maximum strength which the material is capable of producing. The process of increasing the strength may indeed be accelerated if one does not quench the material after heating it to the hardening temperature (500° C.) but allows it to cool slowly. Immediately after this slow cooling, the strength is distinctly higher than that obtained by quenching from the hardening temperature. On storing, however, only a slight change in the tensile strength occurs in the slowly cooled material, while the quenched material comes to far surpass all the tensile properties of that which is slowly cooled. Figure 338 (I, II, III) shows these facts. Naturally, the figures for tensile properties are also lower when the material is subsequently cold worked. The higher the tensile property values lie after the heat treatment, the higher they will become after a subsequent cold working. Accordingly, one dare not subject the material to any process of working directly after the heat treatment, since the properties are low immediately after heating to the hardening temperature, as shown by Fig. 338. Since the tensile properties obtained by the cold working are dependent upon those of the original material, the tensile property curves are all parallel, so that working immediately after heat treatment would produce very inferior tensile properties. By cold working the material without waiting for the aging to take place, the ability to develop itself is taken away from the material. This is shown in Fig. 339.

If, after heating to the hardening temperature and subsequent quenching, the material is heated in boiling water, the conditions are analogous to those in metal slowly cooled after heating to the hardening temperature. The tensile property values then rapidly increase, as if the material had been slowly cooled after heating at 500°. Likewise, as in the case of slowly cooled material, the tensile properties produced by subsequent aging are lower. If, on the contrary, one treats material which has been cold worked after the regular hardening process by tempering it in boiling water, then hardness and tensile strength decrease only to an unimportant extent, while considerable elongation is gained, as shown in Fig. 340.

(Continued on page 294)

Fig. 339 — [Shows Desirability of Cold Work After Aging]



A TUBE ILLUMINATOR FOR METALLOGRAPHY

By LeRoy L. Wyman
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DEVELOPMENTS in microscopic illumination during the past few years have led to the wide use of lighting from oblique angles, such as provided for in "dark-field" and the "ultrapak" type of illumination. Oblique lighting is justifiable because of the much more uniform illumination, particularly of rounded or irregular surfaces.

When one observes an irregular object in diffuse daylight, the illumination is uniform, and highlights give little trouble. Thus, if this condition could be simulated in microscopy, much better photomicrographs would result.

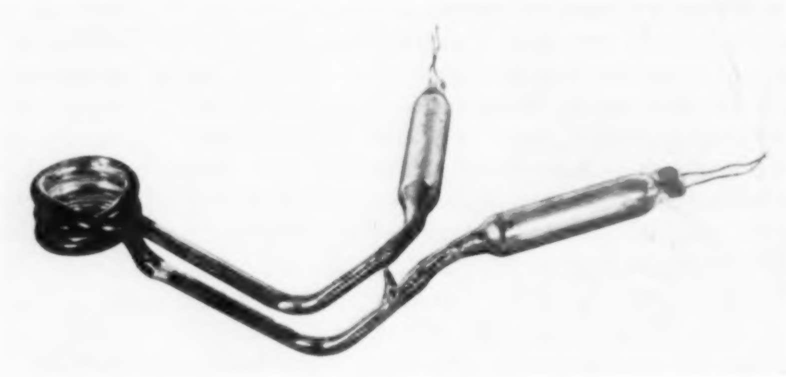
Like conditions may be interpreted in terms of luminous tubes, such as those evident everywhere in modern "neon" signs. A spherical wall of light around the sample reaching every place that can be "seen" by the objective should give the best possible illumination.

Such illumination was approximated by making an evacuated tube into a spiral cylinder which would fit around the objective and sample, and forming the ends leading to the electrode in such manner as to enable the luminous cylinder to be placed beneath the stage of a modern inverted-type metallographic microscope.

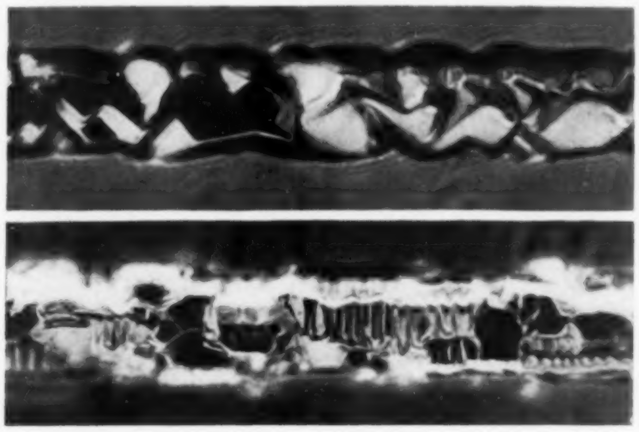
The outer surfaces of the tubes were made reflecting with a layer of vaporized aluminum; they were then painted in order to protect the aluminum film from damage. The reflections set up and converging on the axis of such a cylinder are, of course, beautifully complex and therefore result in a more diffuse light.

Such an illuminator is shown in the accompanying halftone. The auxiliary equipment to complete the unit consists of a suitable clamp by which it is fastened to the microscope, and a high voltage transformer of sufficient secondary voltage. Transformers about the size of those in toy trains are used.

Burned tungsten filaments, magnified 600 diameters, were photographed by means of the above-described equipment, as shown on the opposite page. These photomicrographs illustrate the wealth of detail which can be readily recorded when proper illumination is avail-



First Form of Tube Illuminator, Bent in Form of Short Cylinder to Enclose Microscope Objective



Burned Tungsten Lamp Filaments, Viewed at 600 Diameters, Showing How Illuminator Lights Minute Evaporation Pits on Roughened Surfaces

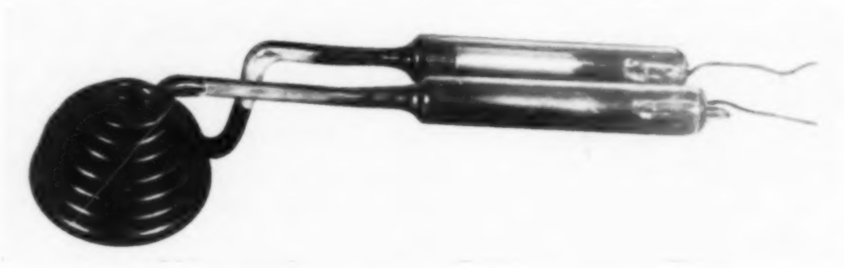
able. Surfaces which appear well rounded under uni-directional light are really covered with tiny crinkles.

A later design which utilizes a considerably greater length of tubing is illustrated in the engraving below. The longer tube length affords even better illumination of the samples.

It would seem that a hollow walled cylinder (or beehive) instead of a coil of tubing would produce within the vessel a uniform wall of light. Unfortunately, however, arcs have a habit of going directly from one electrode to the other, and such would be the case in an illuminator of one-half turn or less.

The luminous tube shown is but one form of lighting, and it is believed the idea is equally applicable to the more modern fluorescent illuminators.

In experiments with this method of obtaining illumination from every possibly useful angle, we found it sometimes desirable to use even larger coils, up to 6 in. diameter.



Beehive Form of Tube Illuminator, Whose Interior Reflecting Surface Approximates a Hemisphere

THE "BODY" OF STEEL

By Carl Benedicks

Abstract from *Blad för Bergshandteringens Vänner*, vol. 23, p. 229, 1938

"*WITH SWEDISH,* Russian or Norwegian iron, one characteristic called 'body' is in especially high esteem in England." With these words, I. P. Morell began a report to a meeting of the Swedish Ironmasters' Association held in 1846 for the purpose of defining that imponderable called "body". Since that time, the term has been used again and again to designate certain characteristics shown especially by Swedish steel. Earlier sources reveal that it had been in use in England since about 1825 to designate three characteristics of steel — *(a)* sufficiently high mechanical properties, *(b)* insensitivity to overheating, and *(c)* a low susceptibility to decarburization.

The cause responsible for the good mechanical characteristics is the purity of Swedish steel — especially its low phosphorus content which in my opinion is chiefly responsible for the fine grain, and its low sulphur content (which is found embedded along the grain junctions and if present in any considerable amount is thus able profoundly to affect the strength of the entire grain structure, especially at elevated temperatures). The cause for the resistance to decarburization lies in the relatively high manganese content. Manganese causes a more stable fixation of the carbon and thus counteracts its oxidation. This agrees with the fact that the well-known steels from Styria and Carinthia (on the German-Italian border) are distinguished by their high manganese.

It is less easy to define the cause responsible for the low sensitivity to overheating (resistance to grain growth) of a steel, since it is known that metals of higher purity — and the steels in question are acceded to be "pure" — also have a marked tendency toward grain growth upon heating. There is thus a contradiction of terms. Some light may be shed on this problem

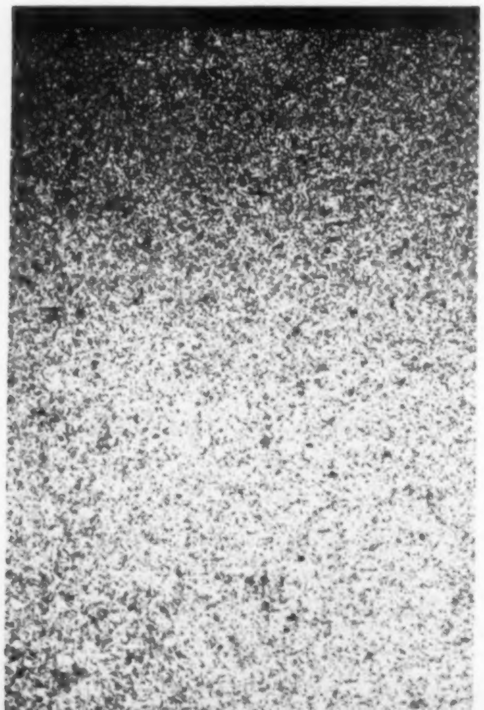
(Continued on page 306)

SMALL PARTS CARBURIZED IN MELTED SALT

By Harry H. Whittingham
Vice-President in Charge of Engineering
Norge Division, Borg-Warner Corp.
Detroit, Mich.

WHEN CONSIDERING the installation of furnaces for carburizing the compressor parts of Norge refrigerators, we considered, among other factors, that furnaces which could be installed directly in the line of production were highly desirable. After due study had been given to such factors as first cost, operating cost, and uniformity of product, salt bath furnaces of the Ajax-Hultgren type were selected.

After a series of tests on some parts under pilot production, it was determined that carburizing in salt at 1650° F. for 4 hr. would case the parts to a depth sufficient to allow for finish grinding, with enough surplus and sufficient depth retained for wearing qualities. When, however, an attempt was made to quench the larger parts directly from the bath, the distortion was such that they would not clean up without increasing the allowance for finishing. These were round plates, up to 6¼ in. diameter. An alternative plan which was found to minimize distortion was to cool the carburized parts in air, and then reheat them to 1450° F. for quenching in oil. But, it was argued, why go to the expense of reheating parts that are already above the desired quenching temperature? After another series of tests, it was found that quenching the parts from the carburizing salt into a similar salt held at 1450° F., allowing the parts to cool to the temperature of the salt, and then quenching them in oil, gave satisfactory results with respect to the case, the core, the hardness and a minimum distortion.



Micro at 100 Diameters Showing Finish Ground Surface at Top, Carburized Case and Gradual Transition to S.A.E. 4620 Core

The accompanying view shows some of the compressor parts (decorated with the inevitable oily finger prints) and the partly loaded fixtures in which they are charged into the furnaces. Such parts are delivered to the furnace rough ground, washed and dried, and are there put into fixtures as shown. A crossbar, not shown, on the upper end of each central fixture rod, supports the fixture; this crossbar rests upon two adjacent rungs on a ladder-like rack, which in turn rests on the lip of the salt pot.

Two batteries of two furnaces each constitute our pres-

ent installation. Each battery consists of a larger furnace for carburizing and a smaller furnace into which the parts are transferred after carburizing and from which they are quenched. These furnaces are shown in the engraving on page 266. In the foreground, the longer (right hand) furnace is the one in which the carburizing is done and the shorter furnace is the one from which the parts are quenched. The hood is common to both furnaces and the ladder rack mentioned previously can be seen. In the background the other battery of two furnaces can be seen, but the relative positions of the small and large furnaces are reversed. This is for convenience in quenching into a common oil tank shown between the batteries.

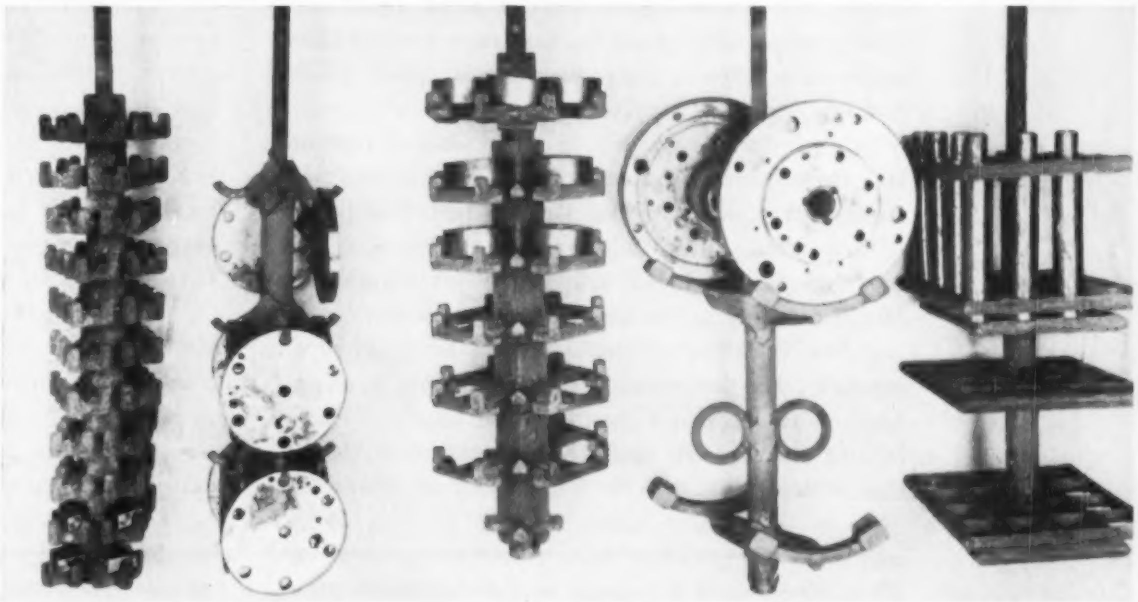
As the operating principle of the furnaces selected has been explained many times by others, it is not considered necessary to repeat in this article, except to point out that the heat is generated directly within the salt bath by means of electrical currents passing between groups of immersed electrodes, so arranged as to circulate the salt automatically by magnetic forces set up at the electrodes. Details may be secured by consulting the article "Electrode Salt Bath for Hardening High Speed Steel" by Axel Hultgren, 1937 *Transactions* ⊕, Vol. 25, p. 1166.

The carburizing furnace has a rectangular pot 7 ft. long, 28 in. wide and 20 in. deep and holds approximately 3000 lb. of salt. It is equipped with three pairs of electrodes and has a connected load of 90 kw. The electrodes are connected to the secondary side of air-cooled stepdown transformers located at the back of the furnace; 220-volt, three-phase, 60-cycle current is supplied to the primary side of these transformers. The furnace load is also three-phase, so the power is balanced evenly on all three phases. Variable voltage taps on the stepdown transformers permit the power input to be changed from the full load of 90 kw. down to 30 kw., so the power can be regulated to meet the production requirements.

The quenching furnace has a rectangular pot 28 in. long, 23 in. wide and 22 in. deep, and holds 900 lb. of salt. It is equipped with two pairs of electrodes. The transformer for this furnace is Scott-connected — that is, three-phase primary and two-phase secondary — so the electrical load is evenly balanced.

Work fixtures carrying the parts are lowered by hand into the carburizing bath held at a temperature of 1650° F. Temperature is controlled by a potentiometer pyrometer and the usual control panel but, due to the active circulation of the salt, one thermocouple at the longitudinal center of the pot keeps the bath within plus or minus 2° F. of the control point. Parts are left in this carburizing furnace for 4 hr., the case obtained being from 0.035 to 0.040 in. thick. The fixture is then removed and, as quickly as possible, immersed in the salt in the smaller furnace held at 1440 to 1460° F. About 15 min. is allowed for the temperature of the parts to fall to the bath, and they are then quenched in oil held between 70 and 150° F. by cooling coils. After removing from the oil they go to a special cleaning solution to remove salt and to coat them with an anti-rusting film.

As mentioned at the outset, the object of transferring the work from the carburizing



Small Refrigerator Compressor Parts Loaded Into Fixtures Prior to Carburizing. Left to right are blades, bearing plates, rollers, cylinder end plates, shafts

bath at 1650° F. to the second bath at 1460° F. is primarily to avoid distortion which might occur if the work were quenched directly from high temperature. Therefore, by this system the work is carburized with the greatest possible speed in the high temperature bath and quenched from the optimum hardening temperature maintained in the low temperature bath. This dual operation is no more costly than the conventional single carburizing-quenching operation because the heat supplied to the low temperature bath by the superheated work just about balances radiation.

Typical parts for compressors of domestic refrigerator units weigh from 0.093 lb. to 6⅛ lb. each. Such parts as blades, rollers and shafts are being made from bar stock, while the others like bearing plate and cylinder end plate are forgings. All are S.A.E. 4620 steel. The surface of the treated parts is clean and bright, the case has a hardness of Rockwell C-61 to 63, and routine tests show a remarkably uniform case not only throughout each piece but from piece to piece.

A photomicrograph of a carburized part at 100 diameters is on page 264. The wearing surface is at the top and the even carbon penetration and gradation is worthy of note. The core hardness is Rockwell B-100 and the McQuaid-Ehn grain size is from 6 to 8.

We find that distortion is held to a minimum by the low quenching temperature. It is such that on the bearing plate (second from left in the fixture picture), which is 3¾ in. in diameter, $\frac{5}{16}$ in. thick, the allowance provided for finish grinding is no more than 0.004 in.

The salt used in the carburizing furnace is a standard grade of commercial activated cyanide. That used in the quenching furnace is a lower melting point salt containing a small percentage of cyanide. The carburizing bath is maintained at from 20 to 25% sodium cyanide by additions of salt as dictated by titration of samples every 4 hr. In addition to the regular hourly additions, each week-end the bath is freshened by bailing out some and replacing with fresh salt.

The salt used operates with a carbonaceous scum. This scum, besides preventing rapid oxidation of the cyanide in the salt, acts as an insulating blanket to prevent excessive heat loss from the surface of the bath.

As a check against bath composition and temperature, test samples are run once a shift and checked for case depth and hardness.

The average production of each battery of furnaces is 320 lb. of small parts per hr. The power consumption averages about 20 kw-hr. per 100 lb. of work treated — a low figure considering that some of the fixtures weigh more than the parts they support. The present pots have been in service for a year and show no serious deterioration; the original electrodes furnished with the furnaces are still in service.

On the whole these furnaces have given a remarkably satisfactory account of themselves, have solved a problem of carburizing parts that must be uniformly cased and not distorted, and are operating in a room with a low ceiling without any discomfort to the personnel.

Heat Treatment Furnaces in Production Line at Norge Division, Borg-Warner Corp., Detroit. Carburizing salt bath is at right foreground, smaller let-down bath next, and oil quench (black tank) in center. Beyond is a reversed pair of salt baths, whose output is quenched in same oil tank

CRITICAL POINTS

By the Editor

SEEMINGLY the Southern Pacific railroad has been "hexed". A year ago in September one of its passenger trains ran at 35 miles per hour into another one standing on a siding and 11 people were killed and 139 injured. Last month the streamliner "City of San Francisco" was derailed at 60 miles per hour and 23 people were killed and 119 injured. These two accidents stand out by their severity in a very good record of safety on the railroads; furthermore, light weight equipment figured in both.

In the collision at Tortuga both trains were drawn by steam engines, both were largely of old steel cars, and both had one or more light weight cars near the front end. These cars had underframe, side trusses and roof of high strength, low alloy steel and side sheathing of stainless steel. In the Interstate Commerce Commission's report we read:

Collision Testing

"The two locomotives were practically demolished and a great amount of the destructive shock was thus dissipated. The destructive shock then progressed backward, doing considerable damage [estimated at $24,500] to these forward cars of standard construction, and further dissipating the destructive force, but the first light weight car in each train suffered the greatest damage [estimated at $100,000 for the two cars] . . . . . The collapse of these cars further absorbed the destructive shock to such an extent that but little damage occurred beyond them."

It is a truism that colliding trains take the most punishment near the front end. To protect postal employees the Post Office long ago set up specifications intended to give ample strength to mail cars, and naturally all equipment (even of the lightest weight) has since met these design standards. These considerations, and the fact that a standard baggage car in the running train was telescoped on one end exactly as far as the light weight car in the standing train, probably led to the testimony of the railroad's engineer of car construction: "Had the passenger car been of standard construction it would have telescoped just as far and as badly and the loss of life would have been as great."

No official report on last month's disastrous derailment is yet available. News and pictorial reports are so recent, however, that it will be recalled that the train was derailed by saboteurs just ahead of a 160-ft. truss bridge over the Humboldt river. Diesel engines in a three-car unit, baggage-dormitory car and a coach hung to the rails and crossed the bridge successfully. The kitchen car broke loose and went down with the bridge when the latter was struck by the dining car, just following. Kitchen car, diner and club car all went down with the bridge, and in these cars the fatalities occurred. Three sleepers followed them into the ravine; the remaining four cars stood upright.

Cars Wreck Bridge

This train was a luxuriously appointed train, put in service on Jan. 2, 1938, making the Chicago-San Francisco run in 39¾ hr. End sills, bolsters and needle beams on the underframe of all cars were welded of high tensile steel. All castings were of heat treated alloy steel. All other framing, including center sills, side sills, posts, columns, roofs and sheathing, was of strong aluminum alloys, heat treated.

While this accident is a "derailment", the damage was done by collision with the steel bridge, its abutments, and the ravine bottom (maybe a trite remark, as all damage in any sort of travel occurs during the sudden stop). So again the interest to metallurgists is in knowing how light weight equipment stands up in collision. It would appear, in this case, as illogical to blame light weight cars for being demolished as it would to blame the steel bridge for being demolished. President McDonald of the Southern Pacific railroad is quoted as having said: "Such an accident under the circumstances would have torn and twisted any train. There were only four of the cars that will have to be scrapped. The other nine are either undamaged or can readily be salvaged and restored to service."

Accidents of this sort are of course greatly to be deplored — better, guarded against by all reasonable means. Nevertheless, it must be admitted that accidents, when they come, are disastrous in geometric ratio to the speed, and if one must have speed, he must face the consequences. The best possible guarantee that *speed* of high speed trains has not yet involved

undue hazards to passengers in light weight cars is that 67 high speed trains are now in daily service in the United States (and 20 more under construction) reeling off 50,000 miles daily, successfully and safely maintaining schedules unheard of before 1934, when the first went into service. Minor accidents have occurred to them, but nothing really serious until the recent derailment. This, however, was not caused by the speed of the train being too much for the tracks, nor was there any suggestion that the casualties were increased by the modern car construction.

In this perilous time for Europe, was reminded of an interesting talk by Charles Leith of the University of Wisconsin, wherein he showed that many wars since the local brawls of the Middle Ages have been fought over the control of important mineral deposits — or at least the settlements have changed the control of these valuable raw materials until now they reside largely in the hands of a few "haves". Whether the control of the raw minerals is all-important, as the good professor of geology would have us believe, few would deny that the post-War efforts of so many governments to be nationally self-sufficient have badly dislocated international trade in raw materials and have had much to do with the prolonged economic depression.

Metals Awry

It is America's good fortune to rank high in the general list of "metallurgical haves", although our "have not" list contains some important items like manganese and chromium (which might be supplied by development of ore deposits in this hemisphere or the utilization of new recovery processes) and like tin, antimony and mercury (which we must bring in from Europe or Asia, or find substitutes).

Germany, in the opinion of Charles Wright, foreign metal specialist in the Bureau of Mines, is worse off in its lack of minerals than any other great power except Italy. Aside from coal and potash it must import large proportions of its necessary minerals. Now that it has lost Alsace-Lorraine to France, it mines only one quarter of its necessary iron ore (and that none too suitable) with only another quarter in sight in southeastern Europe. Austria and Czechoslovakia have supplied the necessary magnesite and most of the 60% deficiency in zinc, while Poland has the rest. Germany's bauxite (aluminum ore) comes from Hungary and Yugoslavia. But even with all southeastern Europe to draw upon, it still lacks three quarters of its required manganese, chromium and copper, half its lead, sulphur and antimony, and practically all of its nickel, tungsten, tin and phosphate (to say nothing of oil, rubber and food stuffs).

One finds here a clear understanding of the German desire for economic or political domination of eastern Europe, and for the recent trade and political accord with Russia, as well as the misgivings of Belgium and Holland with their colonial possessions rich in gold, copper, tin and rubber, and of France with its "redeemed" Alsace-Lorraine. Certainly these inequalities in raw materials have much to do with the present fearful situation. Undoubtedly it would be so costly for many countries, lacking necessary minerals, to industrialize that they will gradually go back to agriculture as their basic activity, relying on sun, rain and the good earth to provide their necessities — and, perhaps, also the raw materials of a future synthetic or plastic age. For the industrialized countries it would be far better for them to trade their raw materials freely than to claw at each other in an impossible attempt to bring *all* of their necessities within their own fences.

Away from these tragic things! Listen to Ted Robinson, philosopher of folly for the Cleveland *Plain Dealer*, comment on a sentence in *Science Digest:* "The value of the chemicals which make up the human body is about 98¢."

Less than a dollar for this mortal clay,
This vital current and these cunning nerves,
This complicated engine that, from day
To day, runs on and never balks nor swerves!
Going, its worth transcends mere golden coin;
Junked, it will bring less than a Small Sirloin.

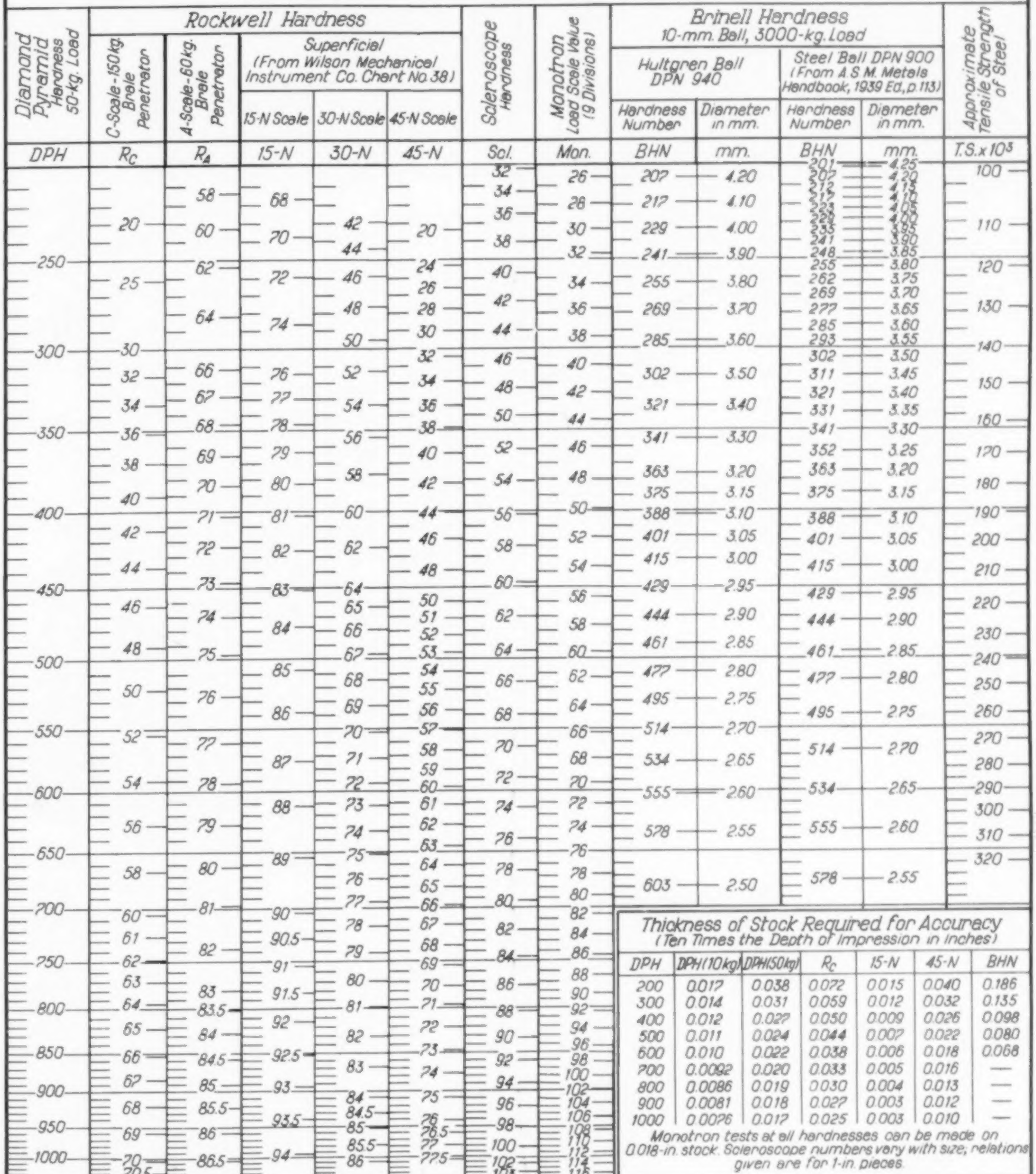
That is, with common people. Let me state
My own Used Body, when the Motor stops,
Would bring a premium on the market rate
If it were peddled at the proper shops.
Why, in my mouth, for instance, there is gold
Enough to buy a coffin, were it sold.

Then take my heart. It isn't worth a sou
Per se — but just go through it when it sheds
Its final ruddy drop, and in it you
Will find a lot of antique arrowheads
Planted by Eros when the world was fair,
Encysted now, but always aching there.

And lastly, make an assay of my head;
I've crammed it full of stuff from modern books,
So it should show a high per cent of lead
With some gold traces in its folds and nooks;
But do not search for iron in my mind —
The Iron's in my soul, which you won't find.

Hardness Conversion for Hardened Steels

By Howard Scott and T. H. Gray, Westinghouse Electric & Mfg. Co.



Thickness of Stock Required for Accuracy
(Ten Times the Depth of Impression in Inches)

DPH	DPH (10 kg)	DPH (50 kg)	R_C	15-N	45-N	BHN
200	0.017	0.038	0.072	0.015	0.040	0.186
300	0.014	0.031	0.059	0.012	0.032	0.135
400	0.012	0.027	0.050	0.009	0.026	0.098
500	0.011	0.024	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018-in. stock. Scleroscope numbers vary with size; relations given are for 1-in. pieces.

In operating any test machine, follow manufacturer's instructions and check frequently against test blocks. Major causes of discrepancy: *(a)* decarburized skin, *(b)* specimens too thin, *(c)* off-standard indenters, *(d)* inaccuracy of machine.

Above conversions are for steel, irrespective of composition and structure, up to its maximum hardness, and for any other material having about 30,000,000 psi. elastic modulus, uniform in depth to bottom of impression. (An exception is that Rockwell test values for shallow hardened steel may be 1 or 2 points higher than by conversion from DPH.) For sintered carbides (DPH 900 to 1700) with much higher modulus the relations between DPH and Rc may be computed from $DPH = \frac{2.445 \times 10^6}{(B - Rc)^2}$ wherein constant B is 118 for carbide (120 for steel).

CORRESPONDENCE AND FOREIGN LETTERS

Special Steels Bought on Analysis

Special Letter to METAL PROGRESS
By FEDERICO GIOLITTI
Consulting Metallurgist, Bessemer Medalist

TURIN, ITALY — In consequence of the ever increasing variety and severity of quality requirements for all metals used in modern industry, frequent changes have been made in specifications — particularly for steels. As other changes will certainly be necessary in the future, it would be interesting, and probably valuable, to study the evolution of the basic principles adopted in recent specifications.

Such an investigation would evidently be very difficult and extensive. It doubtless would show many peculiar differences in the recorded opinions of metallurgists and engineers. A typical example is the diversity of opinion concerning the comparative value of chemical analysis and physical tests.

This instance illustrates once more the great difficulty of finding and adopting general principles for the practical solution of complex technical problems.

The above reflections were called to the mind of the writer by the casual reading of an article in an old number (May 1938) of *The ⊕ Review,* reporting a very interesting lecture by A. Allan Bates on "Modern Trends in Metallurgy". It contains the following statements:

"In the early days of modern metallurgy, great stress was laid on chemical composition, but physical properties were found to vary greatly with steels of the same apparent composition. . . . The future tendency will be to specify the properties desired and leave the composition to the steel maker. This does not mean that chemical analysis is not a useful tool. . . ."

Every metallurgist will agree, as long as the latter statement is applied to tonnage metals, used in structures and machinery which has been carefully designed to withstand stresses of definite nature, and after mechanical and thermal treatments likewise well defined and known to give satisfaction.

But are these the more frequent cases met at present in what might be called metallurgical practice in distinction to routine purchasing of standardized items?

The answer would certainly be negative if this question were asked of a maker of special steels, accustomed to the long and careful researches necessary to discover the small alterations in chemical composition for eliminating troubles arising in given practical applications of steels having shown excellent physical properties when subjected to the most complete and careful laboratory tests.

As a matter of fact, everybody knows that the variety of physical conditions under which metals are used at present is so enormous that laboratory tests can reproduce practical working conditions only approximately. Moreover, in many cases it is simply impossible to reproduce in the laboratory the conditions prevailing in practice. As typical examples one could quote armor plates, armor-piercing shells, gun mountings, rolls or jaws for breaking and crushing machines, large forging dies, hot punching and shearing tools, cuttings tools of every description, barrels for firearms, steam valves.

These well-known facts have been quoted only to call attention to the obvious reasons deterring engineers from adopting principles of too great generality when writing specifications for metals.

If in some cases it may be easy and advisable to "specify the properties desired and leave the composition to the steel maker", in many other cases this policy would be inadvisable, not to say impossible.

In many cases — growing every day more frequent — specifications for both chemistry and mechanical properties are necessary, but close cooperation is then obviously necessary between the user and the maker of the steel, in order to insure that the specifications will be met. This situation is well known to American metallurgists, who are frequently able to command special manufacturing techniques to fit large tonnages of output.

It may be stated that in European practice the tendency (when free choice is possible and the steel production is not rationed by shortages or by trade cartels) is frankly turned toward relying preferably on chemical specifications for special steels. With increasing frequency

— especially when the user can rely on the technical ability of the steel maker — chemical specifications are considered quite sufficient. In any event it may be stated that European steel makers are no longer as opposed as they used to be to accepting *both* chemical and physical specifications — provided, naturally, they are consistent.

In a general way it may be said that in most instances the *class* of a special steel is determined and based only on chemical specifications. Some physical specifications may be added but only in order to insure that that given steel has been properly manufactured and treated. A typical example is high speed steel. Its chemical composition is always specified as being entirely sufficient to determine the class of the steel. A few physical specifications (like hardness after hardening and drawing under given conditions, absence of brittleness) are only added now and then, in order to be sure that a defective manufacturing technique has not damaged the physical properties typical of that class of steel. FEDERICO GIOLITTI

New High Speed Steels

Special Letter to METAL PROGRESS
By M. P. BROWN
Chief of Laboratory, Stalingrad Tractor Plant

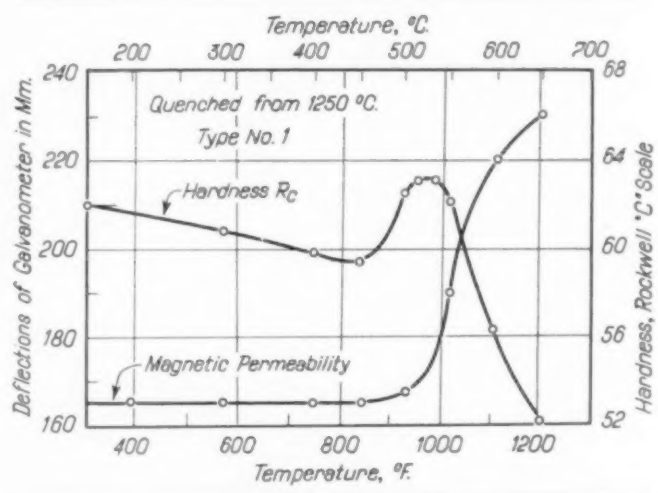
STALINGRAD, U.S.S.R. — The laboratory of the Stalingrad Tractor Plant has studied the suitability of molybdenum-vanadium toolsteels as substitutes for high tungsten ones (high speed steels with 18% W, 4% Cr and 1% V). The following analyses of steels were investigated:

	No. 1	No. 2	No. 3
Carbon	1.1%	1.2%	1.5%
Manganese	0.40	0.25	0.40
Silicon	0.30	0.30	0.30
Chromium	4.2	4.2	4.2
Molybdenum	4.0	4.0	3.7
Vanadium	3.0	4.0	4.0
Tungsten	...	5.0	3.5

Experimental heats were cast from high frequency electric furnace in form of 50-lb. ingots, forged to bars of several diameters and annealed as follows: Heated up to 1575° F. for 5 hr., soaked 2 hr., cooled to 1200° F. in 2 hr., soaked at 1200° F. for 4 hr., then air cooled. Resulting hardness was Rockwell C-25 to 28.

After a number of experiments this schedule of forging was established: Heated in an oil furnace for 5 hr. up to 2000° F.; forging started at 2000° F. and finished at 1650° F. Several reheatings were required for the gradual reduction of the ingots. In general, the steels forge satisfactorily; No. 1 and No. 2 forge much like high speed steel, but No. 3, with an increased percentage of carbon, requires more attention to avoid overheating.

Heat treating schedules were selected after systematic investigations. All were oil quenched from closely spaced temperatures between 1650 and 2375° F. and after every quenching we determined the magnetic permeability, quantity of



Secondary Hardening of Molybdenum-Vanadium Toolsteels (as Well as Increase in Magnetic Permeability) Starts at 850° F. Best tempering temperature is 935 to 1025° F.

residual austenite, hardness and microstructure (the quantity and the form of carbide and the growth of austenitic grain). Magnetic permeability decreased steadily with rising quenching temperature. Rockwell hardness of all three steels was low (C-30) after quenching from 1550° F. It rapidly rose to a flat maximum of C-61 to C-64 when quenched from temperatures beginning at 1950° F. and ending at 2375° F. Hence, the characteristic feature of these steels is a wide range of quenching.

The quantity of residual austenite in the

three steels varies as shown in the following:

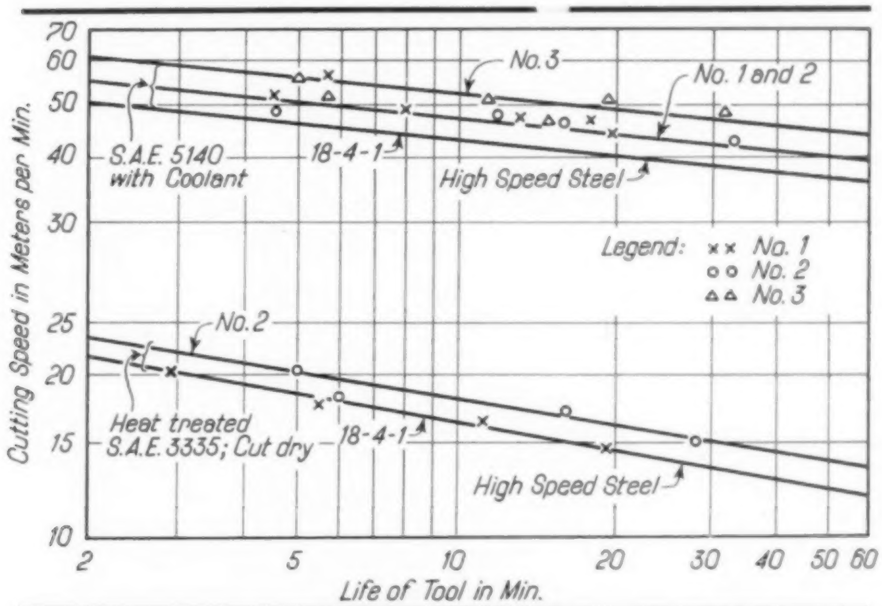
	Quenching Temperature		
	2225° F.	2275° F.	2330° F.
Steel No. 1	36%	38%	43%
Steel No. 2	40	43	49
Steel No. 3	48	49	50

As the temperature of quenching and the period of soaking rise, excess carbides dissolve and austenitic grains grow. When quenching from 2330° F. the 4 to 5-min. soaking is not dangerous. We chose 2225 to 2275° F. as the optimum temperature for quenching all three.

Tempering (single and multiple) at the various temperatures between 400 and 1200° F. was investigated. The first graph shows the magnetic permeability and hardness of No. 1 after tempering. (The curves for No. 2 and 3 are close above the curve plotted.) Increase of permeability and hardness after tempering starts at tempering temperatures of 900° F. The highest possible hardness is after tempering at 965° F. Secondary hardness of all three types is about two Rockwell numbers on the C scale higher than the as-quenched hardness. In general, the tempering can be done in the range between 935 and 1025° F. Multiple tempering at temperatures between 935 and 965° F. gives additional hardness (up to C-65) but 1025° F. must be used for single temperings.

Finally, cutting tools were investigated to ascertain the influence of the following factors: Speed of cutting, depth of cut, feed, hardness, kind and heat treatment of the material being cut, and cooling the tools with a cutting fluid.

Tools tested were quenched from 2265° F. Types No. 1 and 2 were double tempered at 935° F. and No. 3 was triple tempered. Plain chromium (S.A.E. 5140) and nickel-chromium (S.A.E. 3335) steels normalized to 217 Brinell hardness were used for test logs, 7 in. in diameter. The latter steel, heat treated to 340 hardness, was also used. Results on the first mentioned are typical and are shown in the second curve sheet plotted on double logarithmic coordinates. Feed was 0.52 mm. per revolution; cut was 2 mm. deep.



Cutting Speed Vs. Life of Molybdenum-Vanadium Tools and 18-4-1 High Speed. Upper lines are for normalized steels and cutting emulsions; lower lines are for a heat treated steel (Brinell 340) without coolant

From such data the 60-min. cutting speed (with coolant) of standard high speed steel is 36 m. per min. Taking this as 100% the speeds of the molybdenum-vanadium steels are as follows: No. 1 110%, No. 2 110%, No. 3 118%. Similar relationships between the steels exist when the tools are run without coolant.

Lower lines on the same diagram indicate that the new steels are quite efficient when cutting the harder steel without coolant. The 60-min. speed of high speed steel is 12.3 m. per min. and of type No. 2 is 13.5 m. per min., a gain of 8%. Other figures show a gain of 26% when cutting without a coolant the same steel normalized.

General conclusions may be stated thus:

1. The molybdenum-vanadium steels investigated have a wide temperature range for quenching and tempering.

2. Cutting tools are not only of full value

when substituted for high speed but they have an economical speed of cutting from 8 to 26% greater (or a 60 to 200% longer life) than standard high speed steel (18% W, 4% Cr, 1% V).

3. The molybdenum-vanadium steels are better than high speed from an economic standpoint because *(a)* their price is one half to one third that of the high speed steel and *(b)* they can be made from domestic raw materials.

4. Manufacture of cutting tools is not difficult. The only need is to heat them in a salt bath or to powder the tools with borax.

M. P. Brown
Chief of Metallographic Laboratory
A. M. Vlasov and R. T. Evenbach
Investigators

Dangerous Erection Stresses in Bridge Wire

Special Letter to Metal Progress
By William H. Swanger
Metallurgist, National Bureau of Standards

WASHINGTON — The term "mysterious" seems still to be used by bridge engineers in describing the failure of the Mt. Hope and Detroit bridge cables. Studies at the National Bureau of Standards by Mr. Wohlgemuth and the writer clearly established the failure to be due to high bending stresses in the individual wires at the anchor shoes. Changes in tensile load on the wires in the bridge span imposed a damaging range of stress on the material which had low fatigue resistance and caused the failure. The same conditions were present in the cold-drawn material which replaced the heat treated wire but due to a lower modulus of elasticity the initial stress at the anchorage loops was not so high, and because of a slight amount of creep this initial stress gradually decreased. Where static stress conditions exist, fatigue failures do not occur.

If stress measurements are ever made on the individual wires, at the loops around the anchor shoes, as erected on a large suspension bridge, I'm sure the engineers will be surprised at the magnitude of the stress ranges during the construction period, and that these ranges will be dangerously close to the safe limits even for cold-drawn galvanized wires. With the types of strain gages recently developed by A. V. deForest at Massachusetts Institute of Technology, a continuous record of stress fluctuations could be made on individual wires suspended in the same manner as in bridge cables — if interruptions in the spinning operations for such measurements could not be tolerated during the construction of an actual bridge. The results obtained would, I believe, settle any remaining doubts that fatigue stresses were the primary cause of the failures at the Mt. Hope and Ambassador bridges.

The comparatively low fatigue strength of galvanized bridge wire as reported in the Bureau of Standards investigation was verified in the paper by Wampler and Alleman presented at the annual meeting of the American Society for Testing Materials at Atlantic City in June, as briefly noted in "Critical Points" in last month's issue. The magnitude of the fluctuating stress ranges in the cable wires at the anchor shoes during construction remains to be established by direct measurement.

Wm. H. Swanger

Metallographic Terminology

A Correction

A LETTER from F. Poboril on the above subject was printed in the April issue, into which crept some changes in the original meaning during the vicissitudes of translating and editing. Doctor Poboril's definitions should have read as follows:

According to genesis the microstructures in hypo-eutectoid carbon steels should be divided into two main groups:

I. Structures resulting from a direct transformation of the gamma phase.

II. Structures resulting from a rearrangement of other phases or structures.

Both of these groups may be further divided into two sub-groups according to the appearance of the resulting structures:

I_1. Austenite transforming at Ar_1 into a lamellar structure called "pearlite", or at the depressed temperature Ar′ into a very fine lamellar structure called "troostite".

I_2. Austenite transforming between Ar′ and Ar″ into an acicular structure known to be "cubic martensite", or at Ar″ into an acicular structure known to be "tetragonal martensite".

II_1. Acicular structures containing either cubic or tetragonal martensite (that is, the acicular constituents) transform on tempering to a disperse structure known as "sorbite" of varying fineness and homogeneity.

II_{2a}. Acicular structures containing either pearlite or troostite (that is, the lamellar constituents) change during special heat treatment — usually annealing below Ac_1 — into a disperse structure dubbed "globulite" by Prof. Glazunov, a spheroidized carbide of varying fineness and degree of spheroidization.

II_{2b}. Disperse structures containing sorbite (homogeneous or heterogeneous) change during a reheating to temperatures below Ac_1 to a disperse structure consisting of spheroidized carbide of varying fineness and ferrite.

Another Regrettable Error

The photograph on page 143 of the August issue is the property of A. E. Shorter of the Shorter Process Co., Ltd., Sheffield, England, and the caption should have clearly stated that the view was of a Shorter machine. The lapse in the credit line is the more regrettable because it has also embarrassed our friends High Speed Steel Alloys, Ltd., who were kind enough to send the photograph to us.

Characteristic Temperatures of Metals and Alloys

Special Letter to Metal Progress
By Albert Portevin
Consulting Metallurgist, Bessemer Medalist

PARIS, France — Thermal and mechanical treatments of metals and their proper uses require a knowledge of characteristic or "critical" temperatures limiting the thermal zones in which these treatments may be used and studied in each of the alloy systems.

It seems that it should now be possible to systematize these ideas. Such temperatures may be classified in three categories according to the type of phenomena to which they correspond or of which they indicate the occurrence, as follows:

I. Completely irreversible structural phenomena (that is, those that occur only on heating and do not reappear in the inverse direction on cooling). Such are *(a)* the recrystallization temperature Θ_r threshold of recrystallization — the point at which cold-drawn material is transformed in a discontinuous manner on heating into an annealed, fine-grained condition. *(b)* The temperature Θ_g where overheating begins — a temperature marking the beginning of a sudden and very rapid grain growth and which resembles a second recrystallization except that it is not accompanied by the formation of new grains. *(c)* Ill-defined temperatures such as Θ_d and Θ_v might also be mentioned. These mark the point at which diffusion and viscosity in the solid state begin to be noticeable, and may well be taken into consideration in studying or planning a homogenizing anneal. They depend, of course, on the precision with which the respective phenomenon is examined, and since, like recrystallization, they are a function of the thermal agitation of atoms, they may be confused in practice with Θ_r.

II. Phenomena of chemical and physico-chemical transformation accompanied by phase changes. These are reversible with a more or less marked thermal hysteresis or lag, are noted on equilibrium diagrams at a definite temperature, and are often accompanied by important structural modifications. They include: *(a)* Melting and solidification points; *(b)* transformation temperatures such as the critical points in steel. *(c)* The much more ill-defined temperature Θ_t might also be added, indicating the beginning of perceptible tempering of quenched products.

III. Reversible thermal anomalies with no appreciable hysteresis and not accompanied by either structural or phase change. Such are Θ_m, the Curie points of ferromagnetic substances designated as A_0 for cementite and A_2 for alpha iron.

Temperatures in these three categories depend primarily on the metal and the alloy and are an integral part of the knowledge that is indispensable to their accurate treatment and utilization. When the metal presents two allotropic forms (such as alpha and gamma in iron) there are theoretically two series of these characteristic temperatures, each allotropic form acting as a different metal. Practically

some of these characteristic temperatures become fictitious when they fall outside of the thermal zone of existence in that particular condition — e. g., the Curie point of gamma iron.

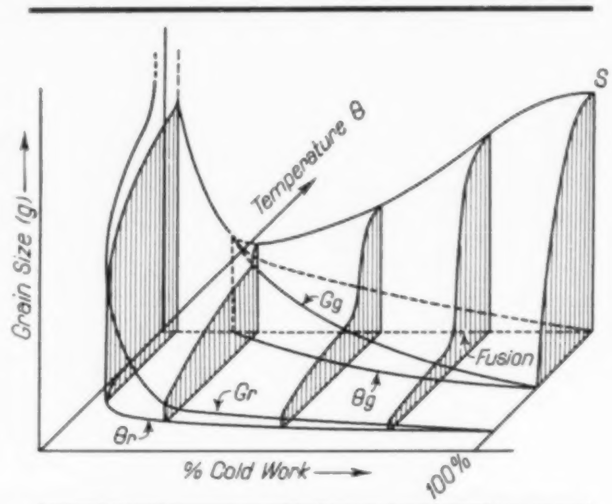
They depend, moreover, on other factors that are quite numerous but whose influence on the different characteristic temperatures may vary. Thus, the cooling rate, which has little influence on the Curie points, may considerably displace the allotropic transformation temperatures; cold working influences particularly the irreversible temperatures of structural modification noted above as Θ_r and Θ_g. This factor is of such importance that it cannot be neglected, and since its influence on grain size after tempering is equally important, three-dimensional diagrams have been constructed of a type shown in the attached sketch, typical of the general appearance of these diagrams, representing the temperatures Θ_r and Θ_g and the grain size g as functions of degree of cold drawing c.

Other secondary factors also have some influence, such as time, grain size and the temperature of initial cold drawing. But one factor which may considerably modify all the characteristic temperatures is the presence of impurities. We are just beginning to have a general conception of the direction in which these temperatures vary under the influence of impurities. Their effect varies with their condition in the metal — whether dissolved in solid solution or as undissolved particles.

Temperatures of anomalies, such as the Curie points mentioned in III above, are influenced by dissolved elements to a degree proportional to the electronic concentration, a product of the concentration by the valence. At least such was the finding of V. Marian in his studies on nickel as affected by Al, Cu, Mo, Sb, Sn, Zn. Undissolved impurities have no effect.

For transformation temperatures accompanied by phase changes, as in II above, undissolved impurities again have no influence on the melting points nor on the transformation temperatures.

The direction and amplitude of variation for dissolved elements depend upon the relative atomic volume and the electronic concentration. These conclusions are the result of sudies by Wever on the transformation points of iron and by Hume-Rothery on the melting points of copper and silver. An estimate of the amount of impurities or addition elements may thus be made by observing the displacement of the transformation points or Curie points.



Ideal Relationship Between Grain Size, Cold Work and Annealing Temperature. Θ_r is recrystallization temperature, G_r is size of grain before reheating, Θ_g is temperature where rapid grain growth occurs, G_g is size of grain just before rapid growth occurs

For temperatures of merely structural transformations as in I, it may be said that in the majority of the cases studied, the impurities in solution raise the temperatures of recrystallization Θ_r and of rapid grain growth Θ_g. Precipitated impurities always act to retard grain growth. Furthermore, precipitated impurities increase the heterogeneity of the superheated grain size (mixed or duplex grain).

In interpreting the influence of impurities, it is essential to remember the possible variation of solubility with temperature, and variation of undissolved impurities and of the influence of the fineness of particles upon the solution rate.

In conclusion, it may be stated that the metals that are most sensitive to recrystallization and to superheating are the purest metals.

Albert Portevin

PERSONALS

Gordon Williams ⊕, formerly metallurgist for Cleveland Tractor Co., is now metallurgist, testing and research laboratories, Deere & Co., Moline, Ill.

Gerald Wadson ⊕ is now metallurgist for the Climax Molybdenum Co., Detroit.

Horace A. Deane ⊕, metallurgist and foundry supervisor for Deere & Co., Moline, Ill., has been appointed assistant works manager of the brake shoe and castings division of American Brake Shoe & Foundry Co., Mahwah, N. J.

Stuart B. MacEwen ⊕ has been transferred to the sales organization of Allegheny Ludlum Steel Corp. in Ferndale, Mich.

Wallace Reen ⊕, who received his M.S. in engineering from Purdue in August, is now doing temperature control work for Halcomb Steel Co., Syracuse, N. Y.

Thomas D. Ketchbaw ⊕, manager, Industrial Welding and Testing Laboratory, Houston, Texas, announces the installation of a complete radiological department for industrial X-ray service.

Roy A. Gezelius ⊕ has resigned as metallurgical engineer for Taylor-Wharton Iron and Steel Co. to become metallurgical engineer for General Steel Castings Corp., Eddystone, Pa.

John F. Perkins ⊕, pyrometric supervisor in the metallurgical department, Carnegie-Illinois Steel Corp., South Works, has been with the organization 18 years and not 18 months, as stated on the Authors' Page, August issue of METAL PROGRESS.

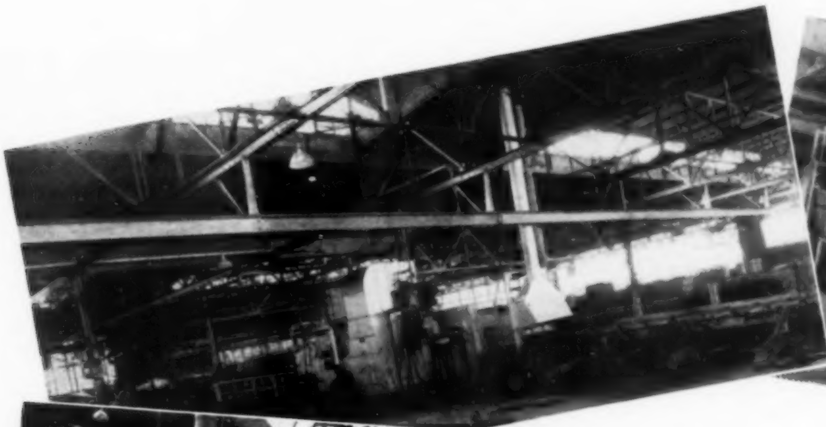
R. W. Sandelin ⊕ has returned to Atlantic Steel Co., Atlanta, Ga., as metallurgist after a year's leave of absence doing graduate work at University of Minnesota.

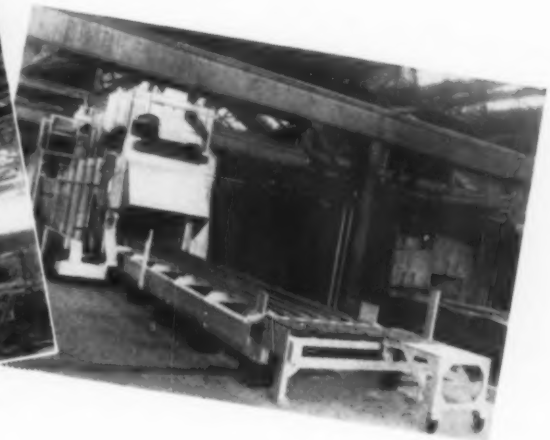
K. A. Juthe of American Electric Furnace Co. expects to return this month from an extended tour of Russia, Denmark, Sweden and other European countries.

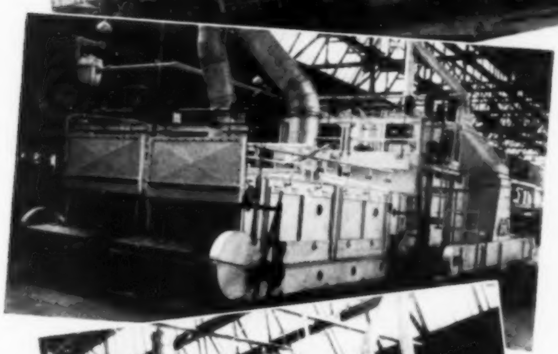
Added to the technical staff of Battelle Memorial Institute, Columbus, Ohio: **Joe C. Danec** ⊕, chemical engineer, assigned to the division of process metallurgy.

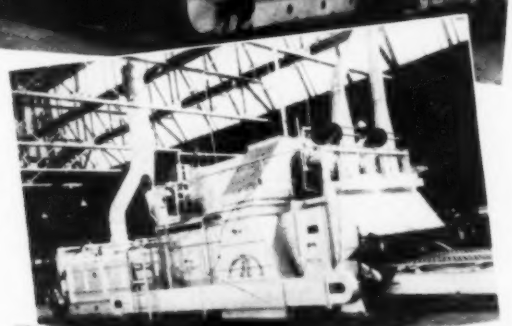
Ralph N. Schaper ⊕ has left Lebanon Steel Foundry where he was planning engineer, to take a position as assistant superintendent, Fort Pitt Steel Casting Co., McKeesport, Pa.

Robert E. Mahr ⊕, B.S. in metallurgical engineering, University of Illinois, is a student apprentice with Allegheny Ludlum Steel Corp.









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PERSONALS

Frank Spitale, B.S. in chemical engineering, Lafayette College, 1939, is now with Beryllium Corp. of Pa., in Reading.

D. B. Nelsen of Indianapolis has been transferred to Chicago in charge of sales for Monarch Steel Co.

Promoted by Jones & Laughlin Steel Corp., Pittsburgh: **H. W. Graham** from general metallurgist to director of metallurgy and research; **C. C. Henning** from assistant to Mr. Graham to general metallurgist.

Appointed vice-president and general manager, Hughes Tool Co., Houston, Texas: **H. W. Fletcher**, formerly chief engineer.

J. H. Vogel has been promoted from assistant works manager in charge of methods and equipment, York Ice Machinery Corp., York, Pa., to general works manager.

Robert B. Gordon, who received the degree of Doctor of Science in Metallurgy from M.I.T. in June, is now research engineer with the Westinghouse Research Laboratories, East Pittsburgh, Pa.

Claus G. Goetzel, research metallurgist for Charles Hardy, Inc., has received the degree of Ph.D. from Columbia University, and is the first metallurgist in the U. S. to receive such a degree on the basis of work in powder metallurgy.

John E. Halbing, formerly works manager Trafford Park Works of Ingersoll-Rand Co., Ltd., at Manchester, England, is now assistant general manager of the company at Painted Post, N. Y.

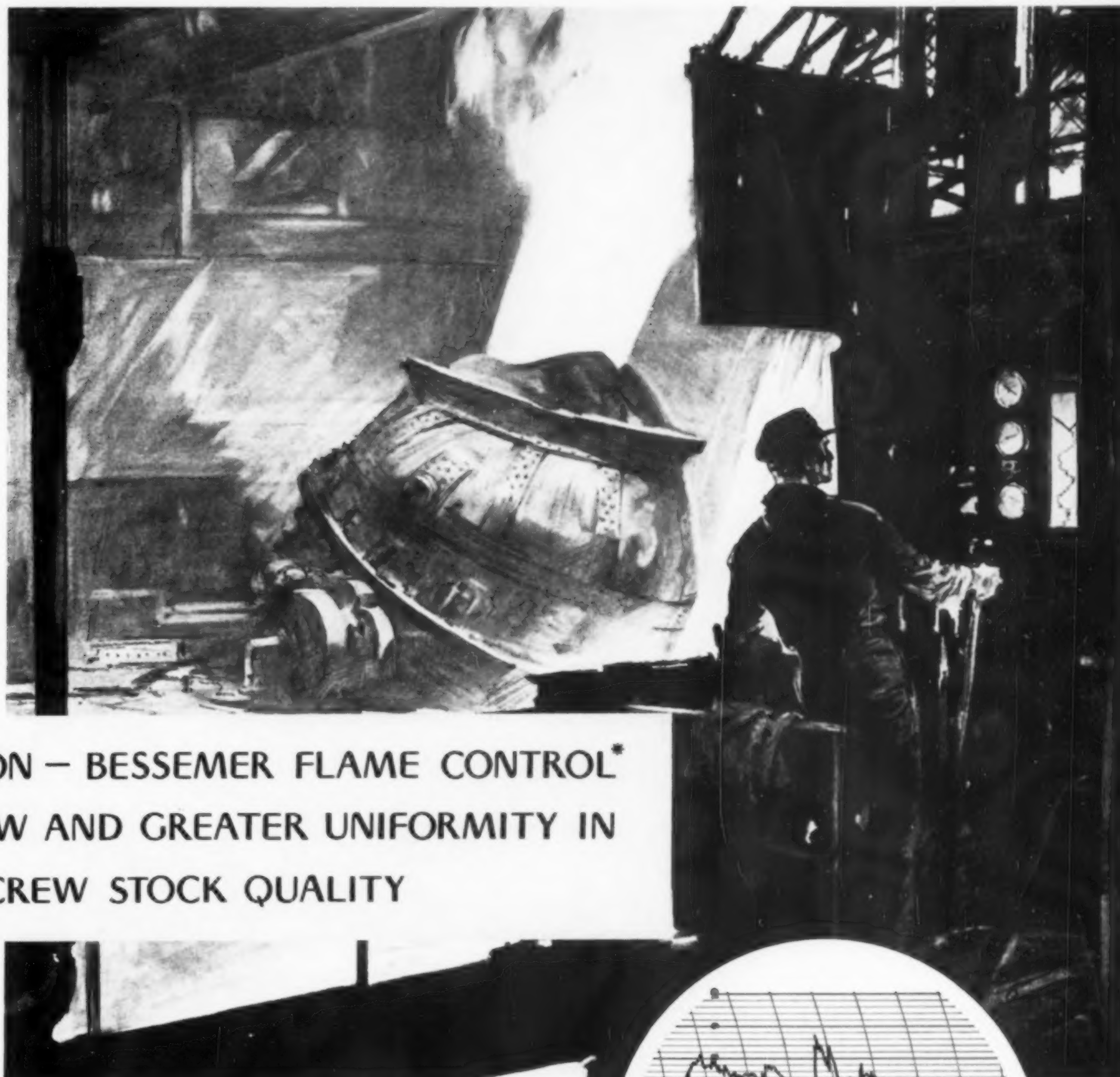
Made chief engineer for H & B American Machine Co., Pawtucket, R.I.: **C. E. Buote**, formerly chief engineer with Foster Grant Co.

Don H. Blackmar is laboratory technician at American Brass Co.'s Kenosha plant, preparing for position as assistant to technical supervisor.

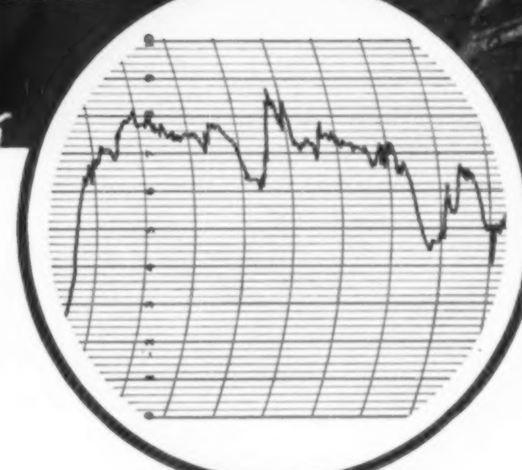
Now metallurgist, Watervliet Arsenal, Watervliet, N. Y.: **William Kahlbaum**, formerly assistant superintendent of research, the Midvale Co., Philadelphia.

Recent appointments by Chas. Taylor Sons Co., Cincinnati, Ohio: **K. I. Gannon**, to the sales staff in St. Louis; **Felix Fraulini**, M.S. University of Illinois and **Donald I. Smith**, M.S. University of Alabama, to the technical staff as ceramic engineers.

B. F. Mercer has been appointed to the steel foundry sales staff of Allegheny Ludlum Steel Corp. with headquarters in Brackenridge, Pa.



J&L INVENTION — BESSEMER FLAME CONTROL* — BRINGS NEW AND GREATER UNIFORMITY IN SCREW STOCK QUALITY



The Bessemer Flame as seen and recorded, with split-second accuracy, by the never-blinking photo-electric eye — feature of the new J & L Bessemer Flame Control process.

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* *Bessemer Flame Control is one of several methods on which patent applications have been filed by Jones & Laughlin Steel Corporation.*

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PERSONALS

Lester Mohrbacher is now heat treat foreman at Cleveland Tractor Co.

L. M. Dalcher has resigned as metallurgist for the Crucible Steel Co. of America to become assistant technical secretary of the American Welding Society.

Thomas V. Brooke, formerly research engineer for Lincoln Electric Co., has been appointed sales engineer in the Chicago office of Lincoln Electric Railway Sales Co.

Appointed manager of the foundry division, Wilkening Mfg. Co., Philadelphia: **W. H. Spencer,** formerly technical director, Sealed Power Corp., Muskegon, Mich.

Transferred: **R. G. Tabors**, from Philadelphia office of Baldwin-Southwark Corp. to Chicago as head of sales activities of the Southwark Division.

Henry J. Chapin is now with Peck, Stow and Wilcox Co. in Southington, Conn.

Frederick M. Gillies has been made superintendent of the Indiana Harbor Works of Inland Steel Co., succeeding **Henry R. deHoll,** retired.

Wayne Mendell has been appointed to supervise the sales activities of the Riehle Testing Machine Division and other divisions of American Machine and Metals, Inc. in Chicago and the surrounding territory.

Appointed by Columbia Steel Co.: **Henry T. Lintott** as general superintendent of the Torrance (Calif.) plant; **O. A. Kresse,** former superintendent of the open-hearth department, to succeed Mr. Lintott as assistant general superintendent.

Newton P. Armstrong has been appointed representative of the Cowles Detergent Co. in New England with headquarters in Boston, and **Frederick H. Hitchcock** has been appointed representative in Detroit and the state of Michigan.

B. D. Christian, formerly general sales manager, is now vice-president in charge of western sales in Chicago for Crocker Wheeler Electric Mfg. Co. **Wallace H. Brown** has been made vice-president in charge of eastern sales.

S. H. Reynolds has been appointed manager of stainless steel sales, Crucible Steel Co. of America, with headquarters in New York. **M. J. McKeever** has been appointed acting manager of Crucible's Atlanta branch succeeding Mr. Reynolds, and **J. P. Larkin** is manager of the magnet department with headquarters in New York.

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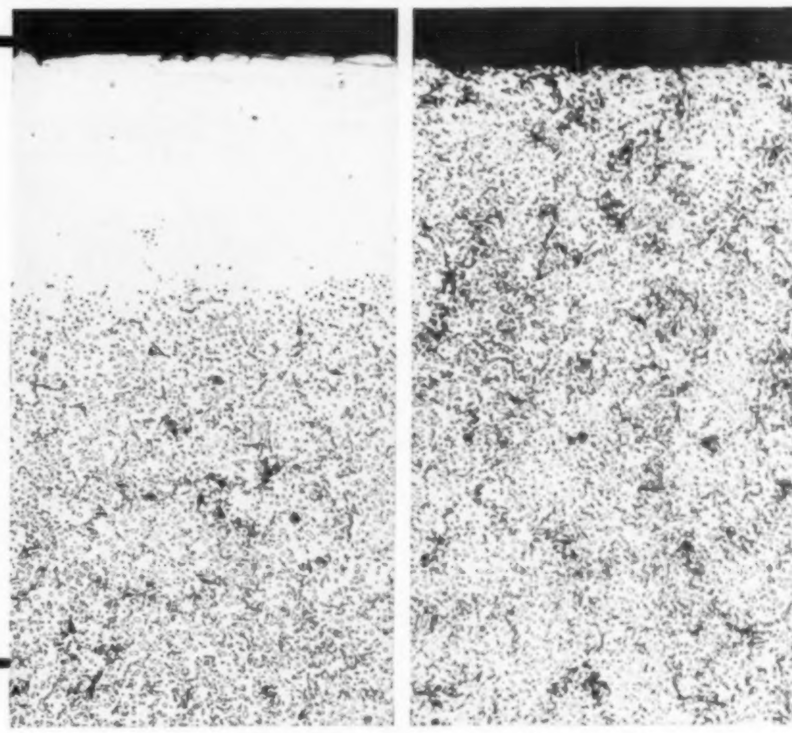
SCALE-FREE HARDENED WITH *NO* DECARBURIZATION

Ordinary Scale-Free Hardening

Micro-section, on left, reveals that decarburization occurs to a depth of approximately .005 inch, when S.A.E. 52,100 Ball Bearing Steel is treated in an ordinary scale-free gas atmosphere at 1500° F. for one hour.



Westinghouse Scale-Free Hardening

Micro-section, on right, proves conclusively that no decarburization occurs when S.A.E. 52,100 Ball Bearing Steel is heat treated in the new Westinghouse ENDOGAS atmosphere at 1500° F. for one hour.

Magnification 500X — Unretouched

S.A.E. 52,100 is but one of many hard-to-handle steels which the recently perfected Westinghouse ENDOGAS atmosphere enables you to harden or anneal with complete freedom from decarburization. In fact, this new process permits scale-free hardening of all S.A.E. steels without "decarb."

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Complete Heat Treating Equipment

D U R A L U M I N

(Continued from page 261)

For special purposes, a subsequent tempering at even higher temperatures is advantageous; thus, for example, it has proved advantageous where sharp threads are cut in the material. In this case, the tempering can advantageously take place in oil at 200° C.; naturally only at those places which on account of the cold work of cutting have a tendency to fracture. In general, just as in the case of other materials from which high elastic limit, hardness and tensile strength are required, one avoids any considerable overheating.

On warming, the tensile strength sinks with rising temperature. In calculating the strength, one must take into consideration whether the material in the object is to be exposed to elevated temperatures. In the case of aluminum alloys containing magnesium, heating up to 150° C. has no appreciable bad effect on the tensile properties, as had been shown by extensive tensile tests at elevated temperature, carried out at the Headquarters for Scientific and Technical Research at Neubabelsberg. However, at temperatures above 200°, the tensile properties decrease considerably.

The properties of the material are influenced to a certain extent by other alloying elements as manganese, nickel, etc. Thus, for example, manganese increases the hardness, while nickel gives a higher toughness. In general, one must proceed very carefully with metallic additions to aluminum, since certain alloying elements tend to produce segregation, even in the case of relatively small additions, and the production of a uniform product becomes doubtful. An addition of manganese, although it must be made within definite limits, has, however, a peculiar effect upon the aluminum alloy. Thus, for instance, such metal is not wet by metallic mercury, while pure aluminum, as is well known, is destroyed in a few hours by the formation of an amalgam.

On account of the high strength which can be given to magnesium-bearing aluminum alloys by this kind of a treatment, they have found a very varied application in practice, especially for military equipment and for use in the construction of airships. The material, commercially produced under the name of "Duralumin", is manufactured on a large scale in Germany by the Dürener Metallwerk Aktien-Gesellschaft, in England by the firm Vickers Sons & Maxim, and in Austria-Hungary by the firm Messingwerk C. Kulmiz, of Kramsach-Achenrain (Tyrol). Interest in this material is continually extending, so that according to all appearances a good future is assured to it.

CONTRIBUTORS

One of the original members of the Norge Corp. on its formation, **Harry H. Whittingham** grew up with the organization (now Norge Division of Borg-Warner Corp.) to become vice-president in charge of engineering. He is an engineering graduate of University of Michigan and was previously employed by Detroit Gear and Machine Co. where he eventually became sales manager.

Born in Chicago, **M. W. Martin** majored in applied sciences at Bradley Polytechnic Institute and upon graduation joined the metallurgical staff of International Harvester Co. He later became associated with the industrial gas department of Peoples Gas Co. in Chicago and Ft. Wayne. Since 1928 he has directed the industrial gas sales and engineering for Public Service Co. of Indiana.

N. B. Lantz's first field of interest upon graduation from University of Cincinnati in 1925 with a degree of metallurgical engineer was in openhearth laboratory control and operation, and during the ensuing two years he was employed by Jones & Laughlin, Otis Steel and American Rolling Mill Co. His interest in industrial gas started when he joined Surface Combustion Corp. as construction engineer, progressing during the next decade to sales and then to process development engineer. He has been with Public Service Co. of Indiana since 1937 as industrial gas engineer for the Newcastle Division.

Louis Walter Kempf, who is research metallurgist in charge of the Cleveland section metallurgical division, has been with Aluminum Co. of America for the past 15 years. Born in 1898 in Muskegon, Mich., he worked in the automobile shops in Flint, Muskegon and Detroit from 1915 to 1917 and was ripe for Army service for the next two years. From 1919 to 1924 he attended University of Michigan. Kempf takes an active part in affairs as chairman of the Publication Committee and vice-chairman of the Cleveland Chapter.

Also a native of Michigan is **A. W. Winston,** an expert on the other commercial light metal, magnesium. He attended Michigan State College, graduating in 1920 with a B.S. in chemical engineering, and sticking to chemical research for the next six years on such products as epsom salt and bromides. In 1925 he joined Dow Chemical Co. and has been working on Dowmetal ever since, first in the metallurgical department, from 1929 to 1934 in plant development work, and again in the metallurgical department, of which he is now director.

A useful byproduct of **LeRoy L. Wyman's** work as research metallurgist at General Electric Co. has been the acquisition of some practical and useful information in improved metallographic equipment and technique. His brief article on page 262 is one instance of this; his chairmanship of Committee E-4 on Metallography of the American Society for Testing Materials is another. Roy Wyman has been at G. E.'s Schenectady laboratory since 1929; the five preceding years he was metallurgist at the Edison Lamp Works in Harrison, N. J. He graduated from University of Minnesota with a chemical engineering degree in 1922 and for the next two years taught metallurgy at Oklahoma School of Mines.

Blackstone

H. H. Whittingham

Frank Moore

M. W. Martin

N. B. Lantz

Louis W. Kempf

LeRoy L. Wyman

A. W. Winston

THE "BODY" OF STEEL

(Continued from page 263)

by studying the factors seemingly fixing the form of crystal grains from molten metals. In steel and iron the speed of growth is not the same in all directions; hence the formation of dendrites. Under the influence of surface tension, however, the grains have also a tendency to develop as small surfaces as possible. The higher the temperature and mobility of the atoms, the more pronounced is the tendency to assume that grain shape which is a function of the capillary forces corresponding to bubbles of foam. Just as in a foam, the surface tension and hence the tendency toward a formation of bubbles of a definite size can be enhanced or reduced by certain small additions, so also in metals definite additions impart stability to the grain boundaries.

The role of such stabilizers of grain size is preferably assumed by such elements as form hard and heat resisting carbides and oxides. An especially high degree of efficiency, however, is ascribed to nitrides among which aluminum nitride would occupy the first place. The view that it is the nitride and not the oxide of aluminum which exerts the profound effect upon the grain size is supported by the fact that acid bessemer steel, having an increased nitrogen content, tends to show a finer grain than open-hearth steel, the latter being poorer in nitrogen. A similar effect is shown by chromium nitride, especially in the stainless steels. There is also a possibility that with Swedish steel, other elements as occur in the respective ores (such as V, Mg, Ti, Zr and Ce) play an important role. (It must, of course, be assumed that these elements, although in very small quantities, pass into the pig iron, and escape scorification in the subsequent conversion into steel.)

There probably exist optimum values for the quantity of effective additions which when exceeded entail the danger of an excessive contamination of the grain boundaries and deterioration of mechanical properties. The secret of the special characteristics of a steel which combined constitute its "body", accordingly, is the proper middle road between purity and contamination, which middle road affords optimum mechanical characteristics as well as a stable grain.

LARGE WELDED BRIDGE

(Continued from page 242)

project; in other words the outside surfaces are smooth. Inside stiffeners are placed at frequent intervals, being in the form of diaphragms with rectangular center holes; they are made of $\frac{1}{2}$x$3\frac{1}{4}$-in. bars with miter cuts on the ends, fitted into the girder and edge welded all around. Triangular gussets reinforce all four inside corners of these stiffeners.

At intervals of about 12 ft. the arches are joined laterally with short cross girders of similar size. A plan view of the bridge before the deck was placed would therefore look like a series of square cells. At each intersection a square column is welded to an appropriate step fitted to the top of the arch, and extends upward to the flat reinforced concrete deck for supporting the roadway.

Each of these arches was delivered for erection in three lengths for the shorter span and in five lengths for the longer span, and was electrically welded in position. At these vertical welds the arch was reinforced by an internal rectangular sleeve projecting from one end and centering the next length of arch. The vertical joint between abutting ends of the web bends off in angles to the left and right at the top and bottom, and at the extremities of the vertical line lugs were welded for bolting together the beveled ends of the arch sections for welding. These assembly lugs were cut off when the weld was completed.

There are no data yet available regarding the economy of the welded structure. Until a few months ago there was too much instability in the matter of French labor rates and working hours to allow of any safe estimate, and all that can be done is to remark on the considerable amount of welding involved, mostly in the shops of the bridge erector. It is affirmed, nevertheless, that there is a saving in the weight of material. The time taken in erection also appears to be much reduced. The welds are tested and verified by drilling out test pieces. For another welded bridge, soon to be erected, verification by X-ray photographs will be employed, though it is believed that the necessity for control will lessen with an increase in the supply of reliable welding operators.